National Park Service
U.S. Department of the Interior

Pacific Island Network
Vital Signs Monitoring Plan

Appendix L: Protocol Development Summaries

Compiled by Karin Schlappa and Heather Fraser (HPI-CESU)

Pacific Island Network (PACN)

Territory of Guam
War in the Pacific National Historical Park (WAPA)

Commonwealth of the Northern Mariana Islands
American Memorial Park, Saipan (AMME)

Territory of American Samoa
National Park of American Samoa (NPSA)

State of Hawaii
USS Arizona Memorial, Oahu (USAR)
Kalaupapa National Historical Park, Molokai (KALA)
Haleakala National Park, Maui (HALE)
Ala Kahakai National Historic Trail, Hawaii (ALKA)
Puukohola Heiau National Historic Site, Hawaii (PUHE)
Kaloko-Honokohau National Historical Park, Hawaii (KAHO)
Puuhonua o Honaunau National Historical Park, Hawaii (PUHO)
Hawaii Volcanoes National Park, Hawaii (HAVO)

http://science.nature.nps.gov/im/units/pacn/monitoring/plan/

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INTRODUCTION

This appendix presents protocol development summaries for 19 PACN Vital Signs. These summaries contain brief justifications for monitoring, a list of parks in which monitoring will be implemented, specific monitoring questions, detailed monitoring objectives, an outline of proposed methods, timeline, and budget, a list of individuals responsible for protocol development, and important selected references. Protocol development summaries primarily serve as a communication device to promote collaboration among networks (by enabling networks to identify who else is working on similar monitoring projects), but they also serve as a placeholder for protocols yet to be finalized, providing planning guidance for investigators before data collection begins.

Phase I Vital Signs

CLIMATE

Prepared by: Karin Schlappa and Fritz Klasner (last modified 5/23/06)

Parks where protocol will be implemented:
AMME, WAPA, NPSA, USAR, KALA, HALE, PUHE, KAHO, PUHO, ALKA, HAVO.

Justification/issues being addressed:
Climate is widely recognized as a major driver for terrestrial as well as marine ecosystems, affecting biotic as well as abiotic ecosystem attributes. Island ecosystems are particularly vulnerable to the effects of climate variability and change (Kennedy et al. 2002, Shea et al. 2001). Of particular concern in the PACN are: effects of increasing solar radiation and temperatures on coral reefs (Craig and Basch 2001), the impacts of shifts in the trade wind inversion on montane to sub-alpine habitats (Loope and Giambelluca 1998), the effects of prolonged El Nino-related droughts on the groundwater supplies (Shea et al. 2001), and the spread of vector borne diseases due to changes in precipitation patterns (Benning et al. 2002). In addition, climatic conditions determine the spread of air pollutants which in the Pacific Island region, result primarily from volcanic point sources. Furthermore, the public safety impacts from climatic conditions are of interest to park managers, from the effects of moisture on fires and fuels, the propagation of airborne volcanic hazards, to the impacts of hurricanes (cyclones) on ecosystems and public safety.

All of the islands in the PACN are located in the tropics. However, the interplay of island topography and global wind patterns often produces dramatically different climate zones over short distances. In many of the PACN parks, basic weather/climate data collection is completely lacking or inadequate. Often local meteorological patterns are not documented; therefore, their effect on the natural resources can not be assessed. Furthermore, identification of climate variability and change, and its effect on natural resources are complicated by the lack of baseline data.

Establishment of a climate monitoring network and database will enable us to characterize an important physical part of PACN ecosystems as required by the Natural Resource Challenge. It will also provide valuable information on current weather conditions for park managers. In addition, long term monitoring will allow us to generate reports on trends and patterns of climate parameters to aid in the analysis and interpretation of other vital signs monitoring. The 'Weather/Climate' vital sign was ranked #12 on the final network-wide VS list. Three individual parks (AMME, WAPA, NPSA) listed this VS among their top 10.

Specific monitoring questions and objectives to be addressed by the protocol:

Objective 1:
Determine variability and long-term trends in climate for all PACN parks through monthly and annual summaries of descriptive statistics for selected weather parameters.

Question 1a: What are the averages (statistical mean) and spread (variance) values for monthly, yearly, and seasonal measurements of core weather parameters (RH, temperature, precipitation, wind speed and direction, cloud cover) on a park-wide, island-wide, network-wide spatial scale?
Question 1b: What are the trends for core climate parameters on park-wide, island-wide and network-wide spatial scales?

Question 1c: What are the long-term trends and spatial extent for other parameters (selected based on site-specific needs) such as, trade wind inversion, lifting condensation level, UV radiation, cloud immersion time?

Objective 2:
Determine frequencies and patterns of extreme climatic conditions for selected weather parameters.

Question 2a: What are the limits of extreme conditions for the core weather parameters (RH, temperature, precipitation, wind speed and direction, cloud cover) on a park-wide, island-wide, network-wide spatial scale?

Question 2b: What is the frequency, spatial extent and duration of extreme weather events such as droughts, tropical cyclones, El Nino cycles, PDO, changes in predominant wind patterns?

Basic approach:
Climate monitoring will rely primarily on historic and active weather monitoring efforts in and nearby PACN parks. If parameters or stations are lacking, additional sensors may be added to existing stations or new long-term stations may be added.

Existing Weather stations: A number of networks/agencies with existing protocols are operating weather stations in the PACN, including: USGS, NOAA-COOP, NOAA-ASOS, NOAA-CMDL, RAWS, HaleNet, and the NPS Gaseous Pollutant Network. Protocols for these networks will be reviewed to ensure that they conform to NPS standards and that data are comparable. This review is being performed as part of a Task Agreement (J8R07050017) between WRCC and NPS.

New Weather Stations: New long-term stations will meet program standards, which will be determined in the protocol development phase, based on specific site purpose and parameters. The protocol will specify standard required parameters and data management methods. Initially new stations will be established at NPSA, and possibly AMME. Both of these parks do not have existing weather stations inside or nearby park boundaries. At AMME there is possibly a NWS station nearby providing adequate data. Exact site locations for new stations will be determined during protocol development using the networks site criteria, including spatial extent and grain for monitoring stations. New station criteria will also incorporate WRCC climate inventory recommendations regarding data gaps and new sites.

Parameters measured: Not all parameters will be included at all monitoring stations, as needs vary by park and at specific sites within parks. Depending on needs, some combination of the following parameters will be included in the weather/climate monitoring efforts: air temperature, wind speed and direction, standard deviation of the wind direction, wind gusts, relative humidity, precipitation, total solar radiation, photosynthetically active radiation (PAR), UV radiation, barometric pressure, fog immersion time, wetness, soil moisture, soil temperature, fuel moisture. The first phase of protocol development will determine which parameters to include for individual stations based on needs for any given park or park unit, as well as informational needs for network-wide comparisons. Consideration will be given to needs specific to the weather/climate vital sign monitoring (e.g., identifying local weather patterns, producing datasets for comparable locations across the network), as well as needs for weather and climate information for other vital signs monitoring and park management needs.

Data management: All weather/climate station data for stations in the PACN area, including those in close proximity to PACN parks, will be incorporated in the WRCC climate inventory database. The database will include maps for easy identification of station locations, as well as metadata for the stations such as: latitude, longitude, elevation, network operating the station, period of record, parameters measured. In the long run, the database will be a useful tool for researchers and park managers by providing easy access to historical and current weather observations. This database will be available online through WRCC. Additional data management procedures will be identified for updating this WRCC product as new data are collected each year.

Analysis and Reporting: The protocol will identify analysis and reporting methods and tools for individual parks or park units in the network. These will include evaluation of the data for diurnal, monthly, annual, seasonal and long-term (decadal) trends addressing our monitoring objectives. In PACN parks that have a sufficient number of stations, spatial analysis will also be included. Furthermore, the range of average (statistical mean) as well as extreme conditions for the various parameters for a particular spatial scale will be identified. Additional reporting criteria will be identified in cooperation with other Vital Sign protocols, and documented as part of this Climate Vital Sign.

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NPS Lead: TBD

Development schedule, budget, and expected interim products:
The schedule presented below (Table 1) reflects the estimated duration of tasks required for protocol development. The investigators' ideal start time is mid 2006; assuming the project starts in July 2006, the protocol will be ready for peer review in July 2007 (FY 2008). Interim products are listed in Table 2.

Table 1. *Timeline of major tasks and products for climate: protocol development.*

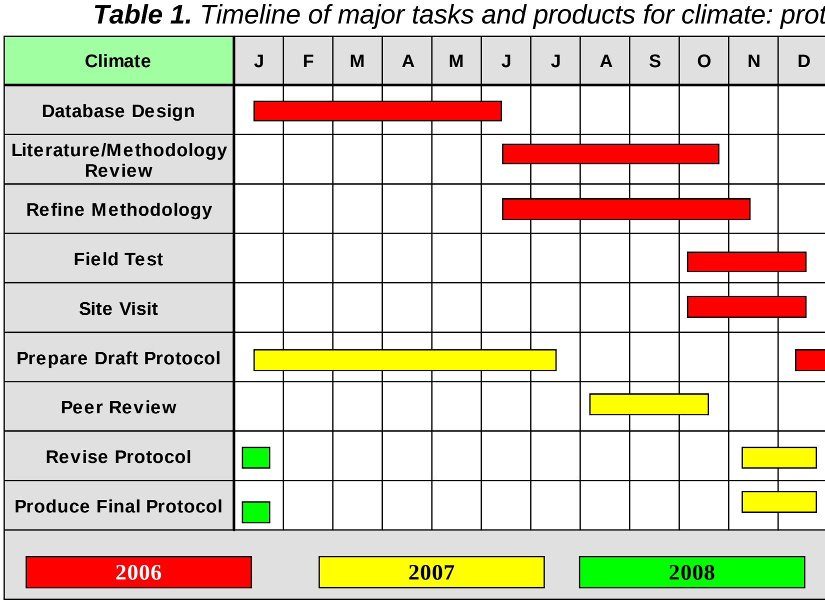

Table 2. Budget for climate protocol development.

Task Description	Start Date	End Date	Cost	Product
1a. Identify historical and active weather stations in PACN. Including station metadata. **1b.** Finalize identification of needs for additional stations/additional sensors at existing stations.	Jan. 2006	July 2006	Funded by national I&M Program.	WRCC inventory products: Database with Climate station metadata. Report, listing weather station locations, adequacy of coverage & identifying major information gaps for PACN parks
2. Finalize, based on WRCC recommendations other PACN climate VS needs: sites, parameters, data analyses procedures.	July 2006	Nov. 2006	$30,000 CESU	Initial draft of protocol.
3a. Draft sample design, data management, analysis, other SOP, appendices, etc. **3b.** Coordination with NWS to integrate PACN monitoring into existing NWS programs and infrastructure.	Dec. 2006	July 2007	$50,000 CESU	Draft protocol
Finalize draft, peer review, incorporate recommendations for change, finalize protocol	August 2007	Jan. 2008	$20,000 – CESU	Final protocol
TOTALS		24 months	$100,000	Protocol

Budget total: $100,000. FY06: $20,000. FY07: $65,000. FY08: $15,000.

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GROUNDWATER DYNAMICS

Prepared by: Steve Anthony, Jeff Perreault, Tahzay Jones (last modified 09/06)

Protocol: Groundwater Dynamics (shortened name: Groundwater)

Parks Where Protocol will be Implemented: AMME, NPSA, KALA, ALKA, PUHE, KAHO, and PUHO

Justification/Issues being addressed:
Groundwater is ecologically important in all Pacific island national parks (NPS PACN 2004) and impacts culturally significant resources. The groundwater (wetland) hydrology Vital Sign was ranked 13th in importance to the PACN I&M Program. Groundwater is the primary source of water for ecologically significant and often rare habitats in the PACN, which include wetlands (AMME, NPSA, KAHO, PUHO, PUHE, and ALKA), anchialine pool systems (KAHO, PUHO, and ALKA), and springs and seeps (AMME, KAHO, NPSA, KALA, PUHO, and ALKA); for municipal water (drinking water for KALA and ALKA); and for agricultural water supplies. Volcanic- and carbonate-rock aquifers in the Pacific are typically highly permeable and unconfined making them vulnerable to contamination. The potential for seawater intrusion is the primary factor limiting development of groundwater resources. Increasing salinity and decreasing flow rates due to escalating groundwater withdrawals will negatively impact ecosystems, habitats and species that have an obligate relationship to groundwater. The declining quantity and quality of groundwater will likely be further compounded by climatic changes and sea level rise.

Long-term groundwater monitoring data are necessary to predict responses of island aquifers and natural ecosystems to changes in sea level, climate variability, groundwater withdrawals, and land use related to urban development. These data can be used to establish trends and to develop models that predict future conditions, and potentially detect groundwater-supply problems for ecosystems, habitats, and species that have an obligate relationship to groundwater supply (both quantity and spatial extent). This information is critical to park resource managers in AMME, NPSA, KALA, PUHE, KAHO, PUHO, and ALKA for protecting and managing wetlands and other groundwater-dependent resources. Cooperation with municipal, county and state projects concerning water resources outside of park boundaries will be necessary.

Based on PACN Board of Director's input in Fall 2005, this protocol will focus on the collection, management, analysis, and reporting of groundwater levels and salinity data. Protocols for assessing the effects of changes in sea level, climate variability, groundwater withdrawals, and land use practices on groundwater levels and salinity are deferred until a potential 'Phase 2', to be initiated at a later date and are not included in this study plan.

Specific Monitoring Questions and Objectives to be Addressed by the Protocol:

Long-term groundwater monitoring is essential for determining changes in water levels and salinity of aquifers that underlie PACN parks. Specific monitoring questions to be addressed by the groundwater hydrology protocol include:

1. What are the seasonal trends in groundwater levels and salinity?
2. What are the long-term trends in groundwater levels and salinity?

Once the groundwater hydrology protocol is implemented in PACN parks, it will be possible to integrate this protocol with related PACN Vital Signs, including climate and land use, to address the affects of sea level rise, climate change, and urbanization on groundwater levels and salinity in a potential 'Phase 2' component of this Vital Sign. Sea-level rise, climate change, and urbanization affect groundwater in different ways and on different time scales. Each of these factors and some of the related monitoring questions are briefly described below. These 'Phase 2' elements will not be addressed in the current planned version of the protocol.

Sea-Level rise is a global phenomenon that can be modified by local conditions in the earth's crust. Estimates of the observed global sea-level rise over the last century range from 1.7 to 2.4 mm/year. Recent projections indicate that rates of relative sea level rise are likely to increase to about 5 mm/year by the year 2100 due to the projected effects of global warming and glacio-eustatic adjustment. The response of coastal groundwater resources to accelerated sea-level rise will likely be an increased tendency for saltwater to intrude both the underlying aquifer at depth and the tidal wetlands at the surface. Some of the specific monitoring questions related to the effects of sea-level rise on groundwater resources include:

1. What is the salinity distribution with depth at selected sites?
2. Will the transition zone between salt and freshwater within the groundwater flow system respond immediately to accelerated rates of sea-level rise, and will this threaten existing public-supply wells?
3. How much farther inland will tidal influence and saline water penetrate the coastal wetlands and associated ecosystems?
4. How will the water balance be affected by sea-level rise?

Climate change is also a global phenomenon with distinctly local aspects that can affect groundwater across a range of time scales. On the basis of data from a network of streamflow stations in Hawaii with more than 80 years of record, Oki (2004) documented climate-induced variations in stream discharge. In general, a statistically significant downward trend in annual base flow was observed. The long-term downward trends in base flow of streams correspond to downward trends in rainfall and may reflect a decline in groundwater storage and recharge. Drought-induced groundwater declines over an extended period can have a large impact on the position of the transition zone between salt and fresh waters; the position of the transition zone (in the absence of pumping by humans) is directly controlled by the aquifer recharge rate, which is sharply reduced during a drought. Finally, it can be inferred that wetland ecosystems in the PACN are similarly affected by declines in groundwater levels, because of the close interaction between groundwater, streams, and wetland ecosystems. Some of the specific groundwater monitoring questions related to the effects of climate change on the groundwater resources include:

1. What are the long-term trends and periodicities in groundwater levels and how are they related to available climatic records?
2. What are the long-term trends and periodicities in discharge from streams and springs to wetlands?
3. Are groundwater, stream-flow, and climatic data correlated, and what can be inferred regarding likely ecosystem impacts of future droughts?

4. What would be the combined effects of projected sea-level rise and drought-induced recharge decline on public water supplies?

Urban development can affect the water balance of a coastal aquifer in several ways, with associated impacts upon human water supplies and coastal ecosystems. (Urbanization can also have large impacts upon ground- and surface-water quality, which will be addressed in other protocol documents). Increased withdrawals for public-water supply or irrigation will reduce coastal discharge and alter the dynamic balance between fresh and salt water at depth in the aquifer. These withdrawals can lead to shifts in the position of the transition zone between fresh and salt waters and possibly cause salt-water intrusion into pumping wells. Urban development also can result in the reduction of aquifer recharge rates (and affect the interface position) by increasing the fraction of impervious surface on the landscape that generates direct surface-water runoff to coastal water bodies. Such changes in the water balance not only affect the interface between salt and freshwater at depth in the aquifer, but also have the potential to directly affect groundwater discharge to wetlands, water levels within wetlands, and the salinity regime in coastal ecosystems. Some of the specific monitoring questions that need to be addressed regarding urbanization include:

1. What are the current and proposed distribution and rates of groundwater withdrawals?
2. Is there evidence that current groundwater withdrawal patterns cause salt-water intrusion and could proposed groundwater withdrawal patterns cause intrusion?
3. Do land-use changes in the urbanizing areas lead to changes in recharge rates (as shown by trends in groundwater levels)?
4. What are the local drawdown effects of groundwater withdrawals on wetland water levels and spring discharge?

Basic Approach:

Groundwater protocols will be developed that include more than a detailed description of field methodology. The protocols will include careful documentation of the questions being asked; the network design and sampling frequency; step-by-step procedures for collecting, managing, and analyzing the data; and expectations on how the data will be presented and used. The U.S. Geological Survey Pacific Islands Water Science Center currently conducts groundwater monitoring using well-defined procedures. As a result, the primary task of this protocol development will be to document the questions being asked and to determine an appropriate network design and sampling frequency to answer the questions. Existing monitoring wells and springs will be identified during a reconnaissance survey. Step-by-step procedures for collecting, managing, and analyzing the data will be developed from standard techniques used by the U.S. Geological Survey in water-resource investigations. The step-by-step procedures will be in the form of modules for monitoring groundwater levels and salinity.

A collaborative scoping process will be used to refine and document the questions to be addressed by the protocol. This will involve a literature review and discussions with NPS personnel as appropriate. It is likely that monitoring sites will be divided into two types of networks: (1) a water-management network to determine the response of groundwater flow systems to human-induced stresses, such as groundwater withdrawals, and (2) a baseline network to determine the response of groundwater flow systems to natural stresses such as sea-level rise or climate variability. The monitoring sites will likely include both wells and springs. An analysis of water-level and chloride-concentration data collected from these networks will be used to answer specific questions to be addressed by the protocol as well as to provide information for the calibration and verification of groundwater flow models, and the design and management of groundwater withdrawal and waste disposal systems.

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Work Schedule: An annual work schedule for major tasks is provided in Table 1. Estimates of the beginning and completion dates for critical segments of the study, including all deliverables, are provided in the list of benchmarks below.

Table 1. *Work schedule for major tasks by federal fiscal year.*

	FY 2005		FY 2006				FY 2007			
	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th
Background research and define measurable objectives, AMME		X								
Reconnaissance survey & network design, AMME		X								
Background research and define measurable objectives, KAHO, PUHE, & PUHO					X					
Reconnaissance survey & network design, KAHO, PUHE, & PUHO					X	X				
Write first draft of protocol						X				
Define procedures for data collection, management, analysis and reporting							X	X		
Define personnel and operational requirements & SOPs							X	X		
Update draft of protocol									X	
Review, revise, and publish protocol									X	X

Budget and Staff: A total of $160,000 will be needed to develop the groundwater protocol. The work will be accomplished by the USGS Pacific Islands Water Science Center in cooperation with the NPS PACN I&M Program. A breakdown by federal fiscal year is provided in table 2.

Table 2. *Breakdown of costs by federal fiscal year.*

	FY2005	FY2006	FY2007	Total
Personnel	11,630	27,848	48,606	88,084
Travel	4,310	7,219	2,400	13,929
Subtotal	15,940	35,067	51,006	102,013
Overhead (36%)	9,060	19,933	28,994	57,987
TOTAL	25,000	55,000	80,000	160,000

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WATER QUALITY

Prepared by: Tahzay Jones, Kimber Deverse, Eric Brown (last modified 09/06)

Protocol: Water Quality Core Parameters (shortened name: water quality)

Parks Where Protocol May Be Implemented: All PACN Parks (WAPA, AMME, NPSA, USAR, KALA, HALE, ALKA, PUHE, KAHO, PUHO, and HAVO).

Justification/Issues Being Addressed:

The quality of surface waters, marine waters, and groundwater is critical to the functioning of aquatic and terrestrial ecosystems across the PACN. Water resources in all National Parks span a range of condition from pristine to highly impaired water bodies. Both point and nonpoint sources impact the waters at various locations (NPS Pacific Island Network 2005b). National Park Service (NPS) management policies mandate that parks will determine the quality of their water resources, strive to avoid anthropogenic pollution occurring within and outside of park boundaries, and "perpetuate surface waters and groundwaters as integral components of park aquatic and terrestrial systems" (NPS 2001). The PACN parks each contain or adjoin marine, freshwater, and groundwater resources. Examples of water body types in the PACN are subalpine lakes, wetlands, coastal and submerged springs, coastal marine waters, shoreline fishponds, anchialine pools, and a saline lake.

All PACN parks are concerned about effects of adjacent land uses and increasing development of watersheds outside park boundaries on park water resources. Water quality core parameters were ranked eighth among vital signs considered by the PACN. The four core parameters chosen for monitoring by the NPS Water Resources Division (WRD) are temperature, pH, conductivity (as salinity for marine waters, as specific conductance for freshwater), and dissolved oxygen. These parameters provide required minimum baseline data for water quality assessment that will be used throughout the NPS (Roman et al, 2003). Turbidity, photosynthetically active radiation (PAR), total nitrogen, total phosphorous, chlorophyll *a*, and depth were added for the PACN due to their ecological significance in the region and will be collected on a water-resource specific basis in addition to the core parameters.

Specific Monitoring Questions and Objectives to Be Addressed By the Protocol:

Question 1: What are the ranges and variances of the network water quality parameters within selected water bodies?

Objective 1: Determine the range and spatial variance on an annual basis of temperature, pH, conductivity, dissolved oxygen, flow/stage/level, PAR, total nitrogen, total phosphorous, and chlorophyll a in coastal marine waters, streams, sub-alpine lakes, rivers, wetlands, a saline lake, and groundwater (with the exceptions of chlorophyll a and PAR in groundwater) in the 11 PACN parks.

Justification: The range of values and their variance for each parameter must be known for the appropriate water bodies (e.g. anchialine pools in KAHO) to assess water quality in parks. Pacific island water-resource types can exhibit a high degree of spatial variability, and the amount of sampling required to capture the variability and range must be determined. Therefore multiple samples and a review of existing data for these resources are necessary. In addition to the NPS core parameters, chlorophyll a, PAR, turbidity, and nutrients are needed to evaluate water clarity and nutrification in marine waters, wetlands, anchialine pools, lakes, rivers, and streams.

Question 2: What are the temporal and spatial trends of the network core water quality parameters for individual water bodies or water resource types in each park?

Objective 2: Determine the temporal (events, diurnal, seasonal, annual, decadal) and spatial trends, for temperature, pH, conductivity, and dissolved oxygen in coastal marine waters, streams, sub-alpine lakes, rivers, wetlands and groundwater in the 11 PACN parks. If necessary, collect and analyze pilot field data to resolve knowledge gaps.

Justification: In order to utilize water quality time series data to identify temporal and spatial trends, the variability for each parameter over time and space must be known. Range and variability of the water quality parameters may correlate with temporal patterns of drivers and stressors and therefore will be necessary to evaluate changes in other ecosystem components. Temporal trends will not be identified for all parameters at all scales, rather a subset will be identified based on known and expected parameter variability and relevance to resource condition.

Question 3: How do water quality parameters within park watersheds change with varying land use patterns adjacent to park boundaries?

Objective 3: Determine the temporal water quality trends in individual park water bodies, while documenting changes in land uses within watersheds. Identify specific water quality parameters (core or other) that may be affected by or correlated with specific land uses.

Justification: Park managers are concerned about and have been involved in extensive negotiations regarding land use change and its impact on park water quality (e.g., KAHO light-industrial park development, or AMME Garapan Flood Control Project). While land use may affect parameters proposed for monitoring above (e.g., erosion and runoff manifest in higher turbidity, fertilizers contribute to nitrogen loading), additional contaminants may also be introduced (e.g., heavy metals, toxins, microbial pathogens). Ideally, monitoring for potential contaminants will occur once the contaminants have been identified through this protocol development, a review of expert opinion and past literature, and potentially new sampling by various parties (with other funds).

Basic Approach:

Water quality sampling is a well developed scientific field. Development of new techniques or protocols is not needed. Rather, this protocol development will utilize a combination of previously defined spatial and temporal sampling designs that are statistically robust with appropriate quality assurance/quality control methods for each of the water resource types of interest to the 11 parks in the PACN. The focus of protocol development will be to tailor the protocol and sampling design to the specific resource type and the individual park. Parks that share a common resource type (e.g. marine waters) will utilize similar protocols allowing for spatial comparisons.

The National Park Service Water Resources Division (NPS WRD) has laid the foundation for water quality monitoring in the PACN. The NPS WRD provides specific guidance on monitoring protocol development, including quality assurance/quality control (Irwin 2004a, Irwin 2004b), and on core water quality parameters for implementation in parks with freshwater, marine, and estuarine resources (NPS 2002, NPS 2003). Characterizations of water resources in PACN park units are described in Appendix I, Water Quality Report, of the PACN Monitoring Plan (NPS Pacific Island Network 2005b). Other national monitoring programs also provide detailed methodologies, statistical sampling protocols, and quality control protocols that will be followed by the PACN. For example, the United States Environmental Protection Agency's (USEPA), Environmental Monitoring and Assessment Program (EMAP) provides basic sample design, methodological, analytical, and reporting guidelines for all water body types. The EMAP design focuses on the condition of ecological resources at spatial scales larger than park units, therefore, existing programs for specific water body types will be used to customize these more general protocols. Guidelines for monitoring marine waters are given by the USEPA National Coastal Assessment Program (2001). For freshwater sampling, the US Geological Survey (2004) water quality field manual provides data collection and quality control protocols. Additional USEPA sources for surface and coastal water monitoring methodologies are available online. The National Oceanographic and Atmospheric Administration's (NOAA) National Estuarine Research Reserve Program also provides water quality monitoring protocols. Other monitoring programs under the guidance of the USEPA Office of Wetlands, Oceans, and Watersheds (OWOW) provide procedures for Total Maximum Daily Load (TMDL) and Beach and Recreational Water Quality monitoring programs.

Review of Water Body and Issue Identification: Park managers need to be aware of the impacts to water quality from neighboring land uses and ecosystem processes. It will be necessary to identify drivers that change water quality for each water body and/or water resource type (e.g., marine waters, lakes, streams, and groundwaters) for each park. For this reason, monitoring the water quality of areas outside of the parks is important to the successful management of resources inside the parks. Potential monitoring boundaries were discussed at a planning meeting to consider water quality components of the PACN monitoring plan and its purpose (NPS Pacific Island Network 2003). Proposed maps of boundaries for water quality monitoring within each PACN park can be found at: http://www1.nature.nps.gov/im/units/pacn/monitoring/plan/2003-pre/waterq/index.htm. Detailed descriptions of each park's water resources and recommendations for specific water body monitoring can be found in Appendix I, Water Quality Report, of the PACN Monitoring Plan (NPS Pacific Island Network 2005b). Protocol development will require parks to implement these specific recommendations.

Review of Parameters to be Measured: Parameters currently identified (NPS Pacific Island Network 2005a) are temperature, pH, conductivity, dissolved oxygen, flow/stage/level, PAR (except in groundwater), total nitrogen, total phosphorous and chlorophyll *a* (except in groundwater). Protocol development will require parks to implement these specific recommendations.

Sample Design: The USEPA's EMAP is a recommended approach for establishing a sampling design, and is particularly well-suited for spatial components within the PACN. This design allows for inclusion of specific water bodies of interest (or past-present monitoring sites), as well as random placement of discrete samples for overall resource assessment. Consultation with statistical experts or EMAP personnel will be required, for example, in some selected water bodies (e.g., KAHO's Aimakapa and Kaloko fishponds) where sampling stations have already been chosen for a current monitoring program. The temporal revisit design will utilize a “never revisit” scheme to estimate status of water resources over the greatest number of sites.

At a smaller spatial scale within water quality areas of interest, additional sites will be selected that are co-located with protocols surveying the benthic community, marine fish, groundwater dynamics, and freshwater animals. These sites will be randomly chosen at the onset within the strata of interest and subsequently monitored to collect time-series data at this fixed location. For example in the marine protocols, the sampling frame of the spatial component will be hard substrates on the reef slope along the 10-20m isobath. The temporal revisit design at the sites of interest will coincide with the other protocols listed above and will most likely utilize a split panel scheme. Consequently, some sites will be monitored continuously using *in situ* instrumentation while other sites will be sampled on a rotating schedule at intervals of 3-5 years. The resulting water quality protocol would incorporate a two-tiered design using the EMAP approach at random locations within a large regional area and the stratified approach for sites of interest at a smaller spatial scale within the park boundaries.

Methods and Measurements: Current monitoring methods will be evaluated to ensure they meet QA/QC standards at least as stringent as USEPA EMAP or NOAA, are considered acceptable by the State, Territory, or Commonwealth, and address monitoring needs. Additional protocols are proposed for current and future monitoring programs to enable comparisons of water quality metrics among the parks. At the randomly selected EMAP sites, it is anticipated that discrete sampling of water column parameters and subsequent laboratory analysis will be standardized across the PACN. Collection of water samples (e.g., nutrients) will follow a rigorous quality assurance/quality control protocol that includes chain of custody records for samples. Laboratory analyses and reporting will also follow a QA/QC plan.

At sites of interest within a park, *in-situ* water quality core parameters will be sampled using instrumentation known as data sondes. These instruments incorporate multiple sensors integrated into a single instrument. Discrete or continuous measurements can be made with the appropriate sonde type. Performance evaluation of several water quality instruments was performed by the NPS-WRD in 2003 (NPS Water Resources Division 2003). The YSI sondes had a slight advantage over the Hydrolab and In-Situ instruments in terms of accuracy, reliability, and servicing (Pete Penoyer, personal communication). Therefore, the initial recommendation is that the PACN parks use the YSI sondes to collect time series data on the four water quality core parameters.

Visual comparisons of aerial imagery before, during, and after land use changes will be used to develop event timelines that can be correlated with temporal trends in the water quality core parameters. GIS analysis of the aerial images will also be used to map and measure the spatial extent of the changes in the adjacent land use.

Initially, the level of sampling effort required to capture any trends in these parameters must be determined from the literature and preliminary field work. The sampling protocol will require the advance purchase of an instrument to collect pilot data for time-series analysis. Evaluation of the field methods will be conducted at a centralized location with personnel from PACN parks to ensure standardization of data collection and interpretation of preliminary results. It is anticipated that this evaluation will take approximately one month.

Data Analysis. Spatial analysis of data from the EMAP sites will follow the USEPA protocol. At the sites of interest, time-series analysis will be utilized for the *in-situ* measurements of the water quality core parameters. Trend analysis using route regression or period mean regression will be employed when analyzing the water quality data sets with other data sets (e.g. benthic marine community) that are co-located and sampled less frequently. The relationship between temporal trends in water quality core parameters and changes in adjacent land use patterns will be analyzed using correlations.

Prepare budget and cost estimates: Review scientific literature and consult with outside institutions and agencies to estimate the cost per unit sample for these parameters by resource type and park. Sample size will be estimated using both a cost-benefit analysis and statistical power required to detect trends for water bodies or water resource type in individual parks. Included in the cost-benefit analysis will be an estimate of how many and what type of instruments will be needed to accomplish the spatial and temporal sampling in all parks. This estimate will be compared to the present inventory of instruments already within the PACN to arrive at a budget for acquiring the necessary sondes. The ultimate limitation on water quality sampling studies is the number of samples required by the statistical design and the cost of analyses for water samples. Instrumentation devised to collect a suite of parameters at once can keep costs low; however, water sample analyses can be costly.

Review with Statistician: A review of methods, QA/QC, sample design, and preliminary results with a statistician will permit the network to ensure quantitative data needs are met and qualitative standards are addressed. While this is an ongoing need, obtaining thorough input will also require a discrete review.

Coordination with other Vital Signs: Coordination and co-location with land use vital signs will be necessary to address correlation of land-uses with changes in water quality. In addition, freshwater biota and marine benthic vital signs also have strong needs for related water quality data. While much of this is addressed in a coordinated spatial sampling design, communication regarding other aspects of this vital sign is required.

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NPS Lead: Eric Brown, Marine Ecologist-NPS, 808-567-6802 x40, Eric_Brown@nps.gov

Development Schedule, Budget, and Expected Interim Products: This monitoring protocol will require 22 months to complete (Table 1) and should be started in October (2005). This schedule insures that field testing is conducted after a suitable protocol has been reviewed and selected.

Table 1. *Timeline for developing the water quality protocol*

	2005								2006												2007				
Task	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M
Protocol Study Plan																									
Submit Draft		X																							
Submit for Peer Review			X																						
Site Visit -- All Parks				X																					
Receive Peer Comments				X																					
Finalize														X											
Hire I&M Aquatic Ecologist													X												
Annual Performance Report				X													X								
Study Design																									
PI & NPS Concept Mtg	X																								
PI Draft Study Design - Phase I			X																						
I&M & Statistician Review I					X																				
PI Draft Study Design - Phase II																	X								
I&M & Statistician Review II																	X								
Receive I&M Comments																	X								
Finalize																		X							
Database Preparation																									
Design Completed																X									
Receive Comments																	X								
Draft Database																	X								
Receive PI Comments																		X							
Submit to I&M																		X							
Receive I&M Comments																			X						
Finalize																			X						
Protocol Development																									
Literature Review		X	X										X	X		X									
Protocol Outline															X										
Protocol Draft																		X							
Receive I&M Comments																		X							
Chapter 2 & Related SOP																		X							
Revieve I&M Comments																		X							
Remianing SOPs Done																			X						
Receive I&M Comments																			X						
Final Draft																				X					
Receive I&M Comments																				X					
Submit for Peer Review																				X					
Receive Peer Review Comments																							X		
Sumbit Final Report to I&M																									X

Budget summary is shown for FY2005 in Table 2, FY2006 in Table 3, FY2007 in Table 4.

***Table 2.** FY2005 costs.*

	FY2005 NPS I&M funds	FY2005 NPS funds (in kind)	FY2005 HPI-CESU Agreement
Personnel			
Aquatic Ecologist (GS-11, 1.0 FTE, w/ 33% benefits, 3 months)			
Data Manager (GS-11 (equivalent), 0.2 FTE, w/33% benefits, 1 month) – shared w/marine group		Budget centrally by PACN	
Biological Tech. (GS-07 (equivalent), 0.2 FTE, w/ 33% benefits, 1 month)			$800
I&M Protocol Facilitator (GS-07, 1.0 FTE w/ 33% benefits, 9 months)			$37,000
Data Manager (GS-11 (equivalent), 0.2 FTE, w/33% benefits, 12 months) (FY06 costs in FY05 agreement)		Budget centrally by PACN	
Biological Tech. (GS-07 (equivalent), 0.2 FTE, w/ 33% benefits, 12 month) (FY06 costs in FY05 agreement)			$10,000
1 x KALA Ecologist (GS-11, 0.4 FTE, w/ 33% benefits, 3 months)		$7,360	
1 x I&M Ecologist (GS-11, 0.2 FTE, w/ 33% benefits, 3 months)		$3,680	
Senior Statistical Consultant (~GS-14 , 1.0 FTE w/ 33% benefits, 1 month)			
Travel			
2 x Inter-island for PI and biotech			$10,340
2 x Hawaii-NPSA for PI			
2 x Hawaii-WAPA for PI			
Materials & Supplies			
Office supplies and misc. field supplies			$1,500
Misc. support supplies			$3,525
Equipment			
Computer, furniture, etc. for data manager/biotech		$1,000	
Vehicle and Vessel support equipment		$5,000	
Water quality data sonde			
TOTAL	**$0**	**$17,040**	**$63,165**

Total FY05 funding requested from PACN I&M: $63,165

***Table 3.** FY2006 costs.*

	FY2006 NPS I&M funds	FY2006 NPS funds (in kind)	FY2006 HPI-CESU Agreement
Personnel			
Aquatic Ecologist (GS-11, 1.0 FTE, w/ 33% benefits, 5 months)		$31,600	
1 x KALA Ecologist (GS-11, 0.2 FTE, w/ 33% benefits, 12 months)		$14,724	
1 x I&M Ecologist (GS-11, 0.2 FTE, w/ 33% benefits, 12 months)		$14,724	

Senior Statistical Consultant (~GS-14 , 1.0 FTE w/ 33% benefits, 1 month)		Budget centrally by I&M	
Travel			
2 x Hawaii-for NPSA resource manager	$6,000		
2 x Hawaii-for WAPA resource manager	$7,000		
2 x Florida for EMAP training	$2,000		
Materials & Supplies			
Office supplies and misc. field supplies	$1,250		
Misc. support supplies		$2,000	
Equipment			
Vehicle and Vessel support equipment		$5,000	
Water quality data sonde	$24,000	$24,000	
TOTAL	**$40,250**	**$92,048**	**$0**

Total FY06 funding requested from PACN I&M: $40,250

***Table 4**. FY2007 costs.*

	FY2007 NPS I&M funds	FY2007 NPS funds (in kind)	FY2007 HPI-CESU Agreement
Personnel			
Aquatic Ecologist (GS-11, 1.0 FTE, w/ 33% benefits, 12 months)		$31,600	
1 x KALA Ecologist (GS-11, 0.2 FTE, w/ 33% benefits, 4 months)		$4900	
1 x I&M Water Quality Technician (GS-7, 0.2 FTE, w/ 33% benefits, 12 months)		$25,000	
Senior Statistical Consultant (~GS-14 , 1.0 FTE w/ 33% benefits, 1 month)		Budget centrally by I&M	
Travel			
2 x Hawaii - NPSA Aquatic Ecologist	$10,000		
2 x Hawaii - WAPA Aquatic Ecologist	$8,000		
1 x Florida for EMAP training	$2,000		
Materials & Supplies			
Office supplies and misc. field supplies	$1,250		
Misc. support supplies		$2,000	
Equipment			
Vehicle and Vessel support equipment		$5,000	
Water quality data sonde	$24,000	$24,000	
TOTAL	**$45,250**	**$70,000**	**$0**

Total FY06 funding requested from PACN I&M: $45,250

TOTAL REQUESTED I&M FUNDS: $148,665

Products: The primary product will be a completed protocol to NPS standards (http://science.nature.nps.gov/im/monitor/vsmTG.htm#Protocols and http://science.nature.nps.gov/im/monitor/protocols/ProtocolGuidelines.pdf). The existing monitoring plan and water quality appendix have identified likely water bodies and issues to be addressed.

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EARLY DETECTION OF INVASIVE PLANTS

Prepared by: Joan Yoshioka

Parks where protocol will be implemented:

AMME, WAPA, NPSA, KALA, HALE, ALKA, PUHE, KAHO, PUHO, HAVO

Justification/issues being addressed:

Invasive alien species pose an enormous threat to the world's biological diversity, believed by most authorities to rank second only to land-use change (Chapin et al. 2000). Hawaii, a state comprised of isolated oceanic islands, has the most severe non-native species problem of any state in the United States (OTA 1993). Other Pacific islands are comparably susceptible (Loope and Mueller-Dombois 1989, Denslow 2003). Documentation in the ecological literature is rapidly growing regarding catastrophic consequences of plant invaders toward native biodiversity and ecosystem processes in island ecosystems (e.g., Huenneke and Vitousek 1989, Meyer and Florence 1996, Lavergne et al. 1999, Buddenhagen et al. 2004, Hughes and Denslow 2005, Asner and Vitousek 2005, Bellingham et al. 2005). Certain high-impact invasive plant species (e.g., *Miconia calvescens*) are likely to overwhelm the national parks of Pacific islands unless concerted intervention by government agencies, nongovernmental organizations, and the public is able to stem the tide of invasions into these islands. The most attractive strategies for invasive alien plant species available include prevention, early detection, and rapid response with eradication or containment, as well as biological control (Hobbs & Humphries 1995). The focus of the Early Detection of Invasive Plant protocol will be on early detection, which contributes to the goals of the NPS PACN monitoring program such as arresting incipient problems before it is too late. The need for early detection monitoring is reflected in the inadequacy of the United States legislation to prevent proliferation of invasive plant species (OTA 1993). Early detection monitoring (described in the protocol) and quick eradication efforts (by partners) are an important stop-gap measure until changes to such existing regulatory systems are made.

Experience in Hawaii (Loope et al. 2004) and elsewhere (e.g., Schuster et al. 2005) indicates that corridor surveys are generally a time and sampling efficient means of locating incipient populations. Road and trail corridors are in some cases significant conduits for spread of specific invasive plant species (e.g., Gelbard and Belnap 2003, Christen and Matlack 2006), especially within parks, because human habitations (where potentially invasive plants are planted) are along roads. The horticultural trade is the pathway by which most non-native plant species reach the islands. This pathway is complex, involving botanical gardens and arboreta, nurseries, seed trade among garden clubs and horticultural societies, the seed trade industry, trade in medicinal and culinary herbs, aquaria, government and private efforts to prevent erosion, etc. (Reichard and White 2001).

The Early Detection of Invasive Plants protocol will describe an innovative and evolving short- and long-term monitoring program to detect invasive species adjacent to and beyond national park boundaries before they become a threat to the natural resources within 10 PACN parks (AMME, WAPA, NPSA, KALA, HALE, ALKA, PUHE, KAHO, PUHO, HAVO). This protocol differs substantially from existing early detection monitoring programs conducted inside parks because it will rely heavily on a concerted monitoring effort by NPS and numerous partners in the buffer and outside park boundaries. Likewise, it is closely tied to rapid response actions conducted by partnering agencies. To fully implement this protocol, collaborative agreements will need to be established among I&M, NPS staff and numerous other agency, NGO, and institutional partners. We envision that implementation will involve NPS staff in areas near the parks (or adjacent to areas of special concern) which are yet to be identified (e.g., buffer around the park). Beyond this area, island partners will increasingly take responsibility for implementation of planned surveys. The precise nature of NPS and I&M Program involvement in monitoring beyond national park boundaries will be determined with input from park superintendents, park management, the I&M Program and partners.

The protocol will focus on: (a) developing a list of target species for each park, (b) prioritizing areas to be monitored based on various decision trees collaboratively developed with the I&M Program, and (c) identify where the priority incipient infestations of invasive plant species exist. The focal areas that will be surveyed will include plant distribution centers or PDCs (e.g., nurseries, botanical gardens), road pathways, and common planting sites (e.g., homes), which have all been identified as major pathways of invasive plant introductions. Other pathways associated with human dispersal will also be evaluated. After management actions are implemented by partnering agencies, follow-up monitoring of the sites and surrounding areas will determine the distribution and abundance of incipient individuals and populations.

We intend for this protocol to serve as a model for cooperative conservation efforts for the early detection of invasive plants throughout the Pacific Islands, which identifies practical methods for short- and long-term monitoring, as well as long-term responsibilities of partners. Development of this protocol in conjunction with the Status and Trends of Established Invasive Plant Species protocol (which develops methodologies for early detection of invasive plants within park boundaries) will be an important step in creating comprehensive long-term monitoring and biodiversity conservation programs for PACN parks.

Specific monitoring questions and objectives to be addressed by the protocol:

Question 1: What are the priority incipient infestations of invasive plant species that require, and are feasible for, rapid response to protect the PACN Parks, and where are they located?

Objective 1a: Develop and maintain a list of targets. These targets are known incipient invasive plant species that potentially pose threats to a park through causing major ecological or economic problems if they were to become established and spread. These would normally be species that are not currently known to occur in a park and are not widespread on the island where the park occurs. However, if a target species is widespread but not known to occur in the park, the species will be placed on the target list for buffer areas around parks. Prior to surveillance, this list will be reduced to a manageable size using a prioritization scheme and knowledgeable experts on the subject.

Objective 1b: Develop and implement an optimal search and reporting strategy (survey design) for invasive plants based on sampling to efficiently cover large areas. Review survey results with local experts to obtain supplementary data. Enlist supplementary voluntary public reporting.

Objective 1c: Working with partners, refine knowledge of dispersal pathways, develop sampling frames, and search high-risk sites (e.g., potential “plant distribution centers,” including nurseries and botanical gardens) for targeted incipient populations of invasive plants.

Question 2: What is the distribution and abundance of the incipient target invasive plant populations observed during the surveys?

Objective 2: After an incipient population of target species is detected at focal sites, monitor the distribution and abundance of the population and survey surrounding areas for satellite populations within 3 months of detection. The total area surveyed will be based on life history attributes, dispersal modes, invasion corridors, vectors of spread, invisibility, and number and size of known locations.

Justification: Early detection of targeted ecosystems that are modified or displaced by alien species will provide data needed to prioritize rapid response to prevent invasions and subsequent damage to National Park resources. External threat detection will serve as an early warning system for park managers to watch out for detected species encroaching on park ecosystems.

Basic approach:

The protocol for early detection of invasive plants will detail recommended methodologies to conduct surveys for targeted species along road and trail corridors (outside parks), surveys of plant distribution centers (e.g. nurseries, garden stores, botanical gardens) and places where plants are imported and distributed, and expert interviews.

Determining the list of targeted species will involve a review of literature and interviews of available experts to determine appropriate targets for each island context. In the Hawaiian islands, for example, information is gleaned on the distribution, abundance, known or likely impacts to natural areas, and legal ("noxious weed") status in other areas, especially on neighboring islands. Substantial information is available from the Pacific Island Ecosystems at Risk website (www.hear.org/pier) and other literature and electronic sources (e.g., Space and Falenruw 1999 for Guam and Saipan, Space and Flynn 2000 for American Samoa). From the NPS perspective, whether the target species is considered a potential threat to national park biodiversity and ecosystem functioning is of paramount consideration. Target lists will be developed using select prioritization tools. A target list may consist of only a few species or as many as 100 species, or more. Availability of experienced or well-trained observers is crucial. The NPS and other partners will review and develop the prospective list to ensure coordinated effort, which is a vital key to success.

Protocol development will include determining a systematic method of surveying these off-corridor areas. When individuals of uncommon incipient species are found and off-corridor access (permission) is available, such incipient populations can be explored to assess potential for eradication. One potentially efficient method of such exploration is using (randomly-located) transects perpendicular to the corridor (Rew et al. 2006). Success of eradications depends on accurately delimiting the distributional extent of a target species (Rejmanek and Pitcairn 2002, Panetta and Timmins 2004, Panetta and Lawes 2005), although life history attributes are also very important. Rigorous evaluation of eradication feasibility is beyond the scope of the protocol but the PACN I&M team should work closely with partnering rapid response teams to ensure eradication is achieved (see Cacho et al. 2006).

In the protocol, the roads/trails selected for island-level and buffer-level monitoring will be defined and identified. Selection of roads/trails for surveys is simpler on small islands (e.g., Tutuila, Ofu and Tau (America Samoa), Maui, Molokai, Guam, Saipan), where it is possible and highly desirable to survey all roads and corridors. Access to private land and roads may dictate areas to be surveyed. A procedure for requesting access to private lands and roads will be formalized in the protocol. The primary survey method will be windshield surveys, which have been successfully applied to the 728 square mile island of Maui, the 2nd largest Polynesian (excluding New Zealand) or Micronesian island (Loope et al. 2004). It is undetermined whether the 4,000+ square mile island of Hawaii island is amenable to the same approach. If not, surveys may be conducted on roads/trails near the parks, based on areas identified as high priority and availability of resources, or will be stratified based on road and corridors type. It is imperative that a consortium of partners on each island be developed to implement the monitoring of which the I&M program, NPS staff, or partnering agency will participate. The protocol will include examples of partnerships on each island, with the understanding that the partnerships will reflect different levels of involvement and commitment and implemented at various stages of the protocol.

Surveying of plant distribution centers (PDCs) will depend on obtaining PDC cooperation and/or legal access in conjunction with local Departments of Agriculture. The ability to monitor what plant species are being sold is clearly desirable where it is feasible. In practice, this will depend on the effectiveness of the local partners who will be implementing this portion of the ED monitoring. Methodology for efficient electronic data collection, involving use of GPS, will be detailed, as will data management, analysis, and reporting.

The Early Detection of Invasive Plants protocol will be cross-linked with other PACN protocols to ensure comparability in sampling and co-visitation. Since these protocols are focused on threats external to park boundaries, co-location of sampling sites will generally not be possible, other than with Landscape Dynamics protocol. Quality assurance procedures will be considered in protocol development. The PACN data manager will provide assistance in database design. PACN Park facilitators will provide assistance with literature review and available data capture for protocol development.

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NPS Lead: Stephen J. Anderson, Natural Resource Program Manager-NPS, 808-572-4480, Stephen_J_Anderson@nps.gov.

Development schedule, budget, and expected interim products:

The P.I. and his team will produce a protocol for PACN for collaborative early detection and reporting of invasive plant species for peer review by March 1, 2006. Salary funds will be used to hire Forest and Kim Starr to assess protocols used in the past by themselves and others, develop data management strategies with PACN and partners (especially PBIN for interface with early detection reporting system), and to assist L. Loope with drafting the protocols. Salaries and fringe benefits via RCUH come to $3600/month for a total of 22 months of salary/benefits. Total is $79,200 in salary and benefits. $2,000 is available in CESU for interisland travel. Total funding requested from PACN I&M (I&M + CESU Agreement): $93,250. The budget summary table follows (Table 1).

Table 1. *FY2005 and FY2006 costs.*

	FY2005 NPS I&M funds	FY2005 HPI-CESU Agreement	FY2006 HPI-CESU Agreement
Personnel			
Lloyd Loope			

In kind USGS			
Forest Starr 11 months FTE, RCUH		31,400	7,200
Kim Starr 11 months FTE, RCUH		31,400	7,200
Total Salary		62,800	14,400
Travel		2,000	
Subtotal		64,800	14,400
Overhead (17.5%)		11,340	2,710
TOTAL (Subtotal + Overhead)		76,140	17,110

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STATUS AND TRENDS OF ESTABLISHED INVASIVE SPECIES

Prepared by: Jim Jacobi and Linda Pratt (last revised: 8/10/06)

Protocol: Status and Trends of Established Invasive Plant Species within PACN Parks

Parks Where Protocol will be Implemented: AMME, WAPA, NPSA, KALA, HALE, ALKA, PUHE, KAHO, PUHO, HAVO

Justification/Issues being addressed:

Nonnative species invasions present a serious threat to Pacific Island Ecosystems. Invasion by nonnative plants reduces native plant diversity and abundance, and alters vegetation structure. At their very worst, ecologically disruptive species (e.g., nonnative grasses, *Morella faya*, *Miconia calvascens*, *Psidium cattleianum*) are able to completely displace the native vegetation and alter ecosystem processes (Vitousek and Walker 1989, D'Antonio and Vitousek 1992). Nonnative plant invasions can also lead to significant economic and cultural costs. For example, nonnative grasses are responsible for increased fire frequency and spread in wildland urban interfaces, and the loss or alteration of culturally significant species and landscapes. Among the > 4,600 nonnative species established in the Hawaiian Islands, there are 100+ highly disruptive nonnative pest species (Smith 1986, HEAR 2004). These are species regarded as the greatest invasive plant threats to native Hawaiian biota and ecosystems. There are over 105 species identified as disruptive or potentially disruptive in America Samoa; and 133 species identified as disruptive or potentially disruptive in Micronesia (Space and Falanruw 1999, Space and Flynn 2002). Some of these species have not invaded parks, while others are just beginning to establish, and still others have well-established populations that have already displaced native plant communities. For example in Hawaii Volcanoes National Park, among the100+ most disruptive nonnative species, 24 species are abundant and widespread in the park, 33 species are only just beginning to invade areas, and 5 species threaten to invade the park from adjacent lands. In recognition of the severity of the problem and its effects on all of the PACN parks, nonnative species ranked as the number three Vital Sign for the Pacific Island Network. Monitoring of nonnative species is needed for effective management of native ecosystems. For species that are only just beginning to establish in parks managers may be able to reduce or prevent their widespread distribution in the future. Other nonnative species may be too widespread and abundant for complete eradication, so alternative management strategies must be developed based on an understanding of current distributions and potential spread.

Specific Monitoring Questions and Objectives to be addressed by the Protocol:

Question 1: What are the nonnative species that threaten native ecosystems in the PACN parks?

***Objective 1a**:* Periodically compile existing information and develop lists of invasive nonnative species within or just adjacent to (i.e., within 1 mile of the boundary) the PACN parks. This list will be updated at least every five years, or more often if new information becomes available on the presence or impacts of invasive plant species within the parks.

Objective 1b. Prioritize nonnative species to identify the most disruptive exotic weeds that threaten PACN parks. Prioritization of species to monitor will be based on the possibility of plants to impact the native vegetation by competing for resources (e.g., light, space, nutrients) coupled with the reproductive and dispersal potential of the invasive species.

Question 2: What are the changes over time in the distribution and abundance of disruptive nonnative species in the PACN parks?

Objective 2. Determine the distribution and abundance of disruptive nonnative species along major corridors and randomly located belt transects that span plant communities between 0 to 10,000 ft elevation within the ten PACN parks.

Question 3: What are the changes over time in recruitment and spread of populations of target disruptive nonnative species that are of primary concern to PACN parks?

Objective 3. For highly disruptive nonnative species (identified in Objective 1b), determine the stand structure (number of individuals in different size classes) and record the reproductive status in permanent plots. For some species the time frame for monitoring and detecting change is very short (e.g., incipient populations of highly invasive species where a significant increase in either distribution or abundance in area will trigger a management response). For other species (e.g., established, highly invasive species) the monitoring time frame may be longer, up to five years, where the objective is to continue to track the spread of a species in cases where management may not be possible.

Justification: Weed risk assessments are needed to identify the plant species that most concern managers and narrow the scope of monitoring. While many nonnative species are invasive, some are more disruptive than others to ecosystems. For example, *Morella faya* completely replaces native forest and fundamentally alters nutrient inputs by increasing nitrogen inputs upto four-fold in areas it invades (Vitousek and Walker 1989). In contrast, *Kyllinga brevifolia* is a widespread invasive sedge whose impacts to ecosystems are unknown but considered by many managers to be negligible. Also, species ability to invade and disrupt will vary across ecosystems. Australian tree fern (*Sphaeropteris coopeii*), a species that invades rain forest, is unlikely to invade dry coastal strand ecosystems.

Many nonnative species first enter the park by establishing along major corridors and high human traffic areas. Monitoring these areas provides an early warning system for the detection of nonnative species just beginning to establish in the park that would enable managers to quickly remove individuals before they become widespread in natural areas.

Long term monitoring of the distribution of nonnative species is required to assess the changing threats to native ecosystems. Managers use the information to formulate appropriate control strategies (e.g., eradication, containment, exclusion, monitoring), and prioritize areas for management.

More intensive monitoring, both spatially and temporally, is required to effectively manage highly invasive and disruptive invasive species. These include species that are just beginning to establish in natural areas, and where large and rapid changes in population growth and distribution are anticipated. The more intensive monitoring allows managers to 1) predict the potential spread of nonnative species into areas of concern, 2) evaluate the feasibility of control within an invaded area, and 3) evaluate the efficacy of control in areas where control has been implemented.

Basic Approach:
The Vital Sign Monitoring Protocol produced during this project will conform to the requirements outlined in the Oakley et al. protocol standards for the NPS I&M program, the NPS I&M program's Protocol Development Process guidance document, and the NPS I&M program Guidance for Protocol Development Summary documents. It will include a detailed narrative describing background information and all aspects of the components of the protocol, as well as a set of Standard Operating Procedures (SOPs) which will describe in detail how each of the components of this monitoring protocol will be carried out, and supplementary materials (e.g., maps, sample databases, etc.) as needed.

Components of the protocol development include:

Compile and prioritize invasive species for each PACN park based on a review of current lists compiled for Samoa, Micronesia, and Hawaii and evaluation of HWPRA and other weed risk assessments.

Review and evaluate existing exotic plant monitoring protocols. Various protocols developed or in the process of development for monitoring invasive nonnative species in Pacific Islands and the continental US (Dunn 1992, TNC 1995, NAWMA 2002) should be reviewed and if possible adapted with modifications to meet the needs of the PACN parks.

Under consideration will be a sampling design for monitoring nonnative plant species along roadsides that is currently being tested on the Island of Hawaii by USGS-BRD scientists (Bio, Pratt, and Jacobi unpubl.). The roadside survey can be expanded to include other major invasion corridors in the parks such as trails, fence lines, and power lines. Species occurrence (presence/absence) in 1 mile segments along corridors is recorded during either walking (preferred) or vehicle surveys. The interval between monitoring is tentatively set at one year but may need to be adjusted to consider dispersal mode, reproductive strategy, life form, and budget constraints.

A tentative sampling design for monitoring nonnative plant species in plant communities that is currently being tested in Kahuku, HAVO by NPS/I&M staff (Loh unpubl.) will be considered. Extensive monitoring is conducted along random start, systematically arranged belt transects that span sea level to 10,000 ft elevation. Wherever possible, sampling is conducted along pre-established transects or transects established in conjunction with forest bird long term monitoring surveys. Additional transects are established to capture nonnative plant occurrence in non-forested plant communities. Occurrence (presence/absence) and crown cover is quantified in 10 m wide belts in 100 m segments along each transect. Width and segment intervals may need to be adjusted to accommodate specific site conditions found in the PACN parks. Percent crown cover of each species is estimated by cover class using modified Daubenmire cover classes (<1, 1-5, 5-25, 25-50, 50-75, 75-95, >95) (Mueller-Dombois & Ellenberg 1974). Monitoring is done at 5 year intervals in a rotating panel design across parks.

Intensive monitoring in plots, to provide predictive information on potential spread of species in different habitats (defined by elevation, precipitation, substrate, slope, aspect), will be limited to the five highest priority species (as determined in objective 1b) for HALE, HAVO, KALA and NPSA. Depending on budget constraints, less or more species and parks may be included in the sampling design. Plots will be randomly located along belt transects and pre-stratified by habitat. Monitoring intervals are based on a split-panel design where a panel of plots is read on two consecutive years (to look at annual survival of individuals and growth of population), and panels rotated across 5 year intervals (to look at trends in spread and occurrence of population). Plots are grouped in panels according to invasive species, habitat, and park.

For both extensive monitoring along belt transects and intensive monitoring in plots, the number and placement of transects and size of plots will be determined by running simulations using existing nonnative species data from the parks and adjacent areas, so that, at least, a 20% change (80% confidence level) in species distribution and abundance is detected.

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NPS Lead: Rhonda Loh, Acting Chief of RM-NPS, 808-985-6098, Rhonda_Loh@nps.gov

Development Schedule:

Jim Jacobi and Linda Pratt are also the PIs for the Focal Plant Community and Species protocol and will work on both of these concurrently. The draft of the established invasive plant species protocol will be completed in March 2007 and submitted for peer review. Final revisions of the protocol will be completed by May 31, 2007.

FY2006

June 2006

- Hire Botanical Specialist (RCUH, GS-9 equivalent) as lead person for protocol development. This person will be coordinating the development of two related protocols: Focal Plant Communities and Species, and Established Invasive Plant Species.
- Complete interagency agreement based on draft of study plan
- Complete study plan and submit for NPS peer review

July to August 2006

- Draft sampling design (i.e., delineate areas, determine necessary sample sizes, determine accessibility, select sampling sites, prepare Minimum Tool Analysis for applicable park units).
- Select and prioritize disruptive focal plant species in each park
- Complete field visits to PUHO, PUHE and KAHO.

September 2006

- Complete field visits to WAPA, and AMME.
- Prepare and submit annual progress report

FY2007

October – November 2006

- Refine SOPs and sampling methodologies for this protocol.
- Complete field visits to NPSA, HALE, KALA, and HAVO.

December 2006 – February 2007

- Prepare protocol documentation and SOPs
- Compile all new data into protocol database

May 2007

- Submit complete draft of protocol and supporting documents and datasets for peer review

July 2007

- Complete revisions of protocol based on review comments and submit to PACN I&M Coordinator
- Provide all datasets, GIS themes, etc., with FGDC compliant metadata to PACN I&M Coordinator
- Submit final project completion report

Budget:

FY2005 costs.

	FY 2005 USGS IAA	FY 2005 NPS Funds	FY 2005 HPI-CESU Agreement	Total Funds
Personnel			21,382	21,382
Travel			1,900	1,900
Materials & Supplies			900	900
Equipment			1,350	1,350
Subtotal			25,532	25,532
Indirect Costs			4,468	4,468
TOTAL			**30,000**	**30,000**

Indirect Cost Amount	*15%*	*0%*	*17.5%*

FY2006 costs.

	FY 2006 USGS IAA	FY 2006 NPS Funds	FY 2006 HPI-CESU Agreement	Total Funds
Personnel			1,500	1,500
Travel	1,500	1,500	2,000	5,000
Materials & Supplies			798	798
Equipment	-		-	-
Subtotal	1,500	1,500	4,298	7,298
Indirect Costs	225	-	752	977
TOTAL	**1,725**	**1,500**	**5,050**	**8,275**

Indirect Cost Amount	*15%*	*0%*	*17.5%*

FY2007 costs.

	FY 2007 USGS IAA	FY 2007 NPS Funds	FY 2007 HPI-CESU Agreement	Total Funds
Personnel				-
Travel	1,500	1,500		3,000
Materials & Supplies				-
Equipment	-			-
Subtotal	1,500	1,500	-	3,000
Indirect Costs	225	-	-	225
TOTAL	**1,725**	**1,500**	-	**3,225**

Indirect Cost Amount	*15%*	*0%*	*17.5%*

The total request to the PACN I&M Program for this project is $ 41,500.

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<u>BENTHIC MARINE COMMUNITY</u>

Prepared by: Dwayne Minton, Raychelle Daniel, Eric Brown, Larry Basch, and Leslie HaySmith (last modified 03/20/2006)

Protocol: Benthic marine communities (shortened name: benthic)

Parks Where Protocol will be Implemented: KAHO, KALA, NPSA, WAPA (ALKA, AMME, HALE, HAVO, PUHE, PUHO, USAR)

Justification/Issues being addressed:
The benthic marine community in the PACN is rich and diversified, including algae, corals, and other invertebrates. In most parks, coral reefs form the structural framework of an ecosystem that has been compared to tropical rainforests in terms of species diversity and the complexity of interactions (Connell 1978). This vital sign is closely linked with the marine fish vital sign, and ideally monitoring efforts would be conducted in parallel to maximize data value. Because of corals role as the primary architectural organism (analogous to trees in a forest) and its sensitivity to environmental degradation, it is a good indicator of overall health for nearshore marine ecosystems. Primary stressors to coral reefs include disease (e.g., white syndrome), bleaching, sedimentation, eutrophication, storms, and global climate change. The United Nations Environment Programme (UNEP) has proposed coral reefs as a worldwide indicator ecosystem for global climate change (Spalding et al. 2004). For these reasons, PACN nominated benthic marine communities as the #2 vital sign for implementation.

Specific Monitoring Questions and Objectives to be Addressed by the Protocol:

1) *What are the changes over time in the composition (e.g., species and/or assemblage) and physical structure (rugosity) of the coral reef benthos?*

Objective 1a: Determine long-term trends in the abundance (density of individuals or percent cover of the benthic substrata) of sessile marine benthic macroinvertebrate (e.g., corals, soft corals, sponge) and macroalgal (including large fleshy, articulated or crustose coralline, and turf algae) assemblages at randomly selected sites stratified by habitat or substrata, along an isobath between 10 and 20 meters depth.

Justification: Long-term changes in the relative abundance of invertebrate and algal assemblages can often be correlated with specific stressors or drivers. For example, an increase in algal cover (generally at the expense of coral) has often been associated with eutrophication or a reduction in the numbers of herbivorous fish or invertebrates.

Objective 1b: Determine trends in benthic small scale topography or rugosity at randomly selected, fixed (permanent) stations that have been stratified by habitat or reef zone (e.g., reef flat, reef slope).

Justification: Rugosity is a measure of structural/architectural complexity of the benthos. Changes in rugosity suggest large scale changes in the benthic community composition, function, and condition. Research has established a strong correlative link between rugosity and abundance of fishes (Friedlander and Parrish 1998) and mobile invertebrates (Minton 2000).

2) *What are the changes over time in reproduction, recruitment, growth, survival and health of target coral assemblage, species, and/or individuals?*

Objective 2a: Determine trends in recruitment rate to uniform artificial surfaces of hard corals (as an assemblage) at selected sites on the fore reef along an isobath between 10 and 20 meters depth.

Justification: Coral populations must successfully reproduce and recruit to persist. Due to their microscopic size and typical occurrence of planktonic life stages, coral larvae are particularly sensitive to environmental stressors (Richmond 1995). Many corals are long lived, and the presence of adult individuals that are less sensitive to stressors than their young stages can mask serious demographic problems. While not immediately evident (e.g., adult population appears healthy), failure to recruit or low recruitment success over multiple years can result in the sudden degradation of the coral reef ecosystem as adults senesce or experience mortality from natural biotic or physical disturbance(s) or anthropogenic impact(s).

Objective 2b: Determine trends in rate of growth and survival of randomly selected coral colonies of a common, trans-Pacific species (e.g., Pocillopora damicornis, P. verrucosa, Porites lobata) growing at similar depth.

Justification: Coral growth rate and survival are indicative of coral and reef health and water quality and provides a time integrated measure of the condition of these factors. Calcification rates are affected by light availability, disease, bleaching, and global climate change. Without continued calcification, coral reefs will be degraded through bio-erosion and mechanical damage. Smaller corals also have lower fecundity and hence reduced reproductive potential.

Objective 2c: Determine long-term trends in the incidence and severity of coral and algal disease and bleaching.

Justification: Emphases of monitoring will be on the physical conditions that are indicative of disease (e.g., the extent of bleaching) and environmental correlates (e.g., temperature) when possible, rather than the diagnosis and causation of disease. Coral disease can cause mortality or produce other sublethal effects. Until recently, coral disease was believed to be less prevalent in the Pacific Ocean, but reports of incidence are increasing in frequency (Aeby 2003). In the Caribbean, coral disease has extirpated species (e.g., *Acropora cervicornis*) from some geographic areas (Aronson and Pretch 2001). Coral disease has been linked to anthropogenic stressors (e.g. sewage/nutrients) and changes in environmental conditions associated with global climate change (e.g., increase in sea surface temperature).

Basic Approach:

A number of existing protocols to monitor benthic marine communities are readily available, including NPS-approved coral reef monitoring methodologies developed by USGS for Virgin Islands NP (Rogers et al. 2001). Unfortunately, many commonly used monitoring methods lack statistical power (Brown et al. 1999) or may need modification to function at PACN parks (e.g. Caribbean coral reefs are different from Pacific reefs, and methods are not perfectly interchangeable). A comprehensive review of these methods is necessary to achieve the program's goal of developing protocols with rigorous scientific merit. The final protocol will employ existing methods where appropriate. Protocol development for the above objectives will follow a standard procedure, listed below as Tasks:

TASK	DEADLINE	LEAD RESPONSIBILITY
Study Plan		
Update Study Plan	14-Oct-05	Brown, Minton, Klasner, Daniel, Basch
Submit for Peer Review	14-Oct-05	Minton
Receive & Incorporate Peer Comments	21-Oct-05	Minton, Brown
Update Study Plan	Mar, 06	Klasner, Daniel
Finalize Study Plan	28-Mar-06	Brown, Minton, Daniel & Klasner
Annual Performance Report	11-Oct-05	Klasner
Study design		
Draft Study Design II	07-Oct-05	Brown
I&M Statistician Review	31-Oct-05	Skalski
Finalize Study Design	04-Nov-05	Brown
Database		
Design Completed	02-Nov-05	Dicus & Snyder
Draft Database	02-Nov-05	Dicus & Snyder
Receive Coral Reef Comments	04-Nov-05	
Incorporate Comments based on Penny's review	Mar, 06	Dicus & Snyder
Final Database	30-Mar-06	Dicus & Snyder
Protocol development		
Protocol Outline	03-Oct-05	Brown & Daniel
Protocol Draft	20-Oct-05	Brown et al.
Draft SOPs	20-Oct-05	Brown et al.
Protocol Development Workshop	31Oct-04Nov	Workshop participants
Incorporate Comments	11-Nov-05	Minton, Daniel, Klasner, DeVerse
Remaining SOPs Done	11-Nov-05	Minton et al.
Draft Protocol	14-Nov-05	Minton et al.
Send to I&M and PICRP for Comments	14-Nov-05	Daniel & Klasner
Receive I&M & PICRP Comments on draft protocol	01-Mar-06	Reviewers
Incorporate Comments	Mar, 06	Brown, Klasner, Daniel, Minton, Dicus, Snyder
Finalize Protocol	April, 06	
Submit for Peer Review	June, 06	I&M – Klasner & HaySmith / Latham
Receive Peer Review Comments	Nov, 2006	
Incorporate Regional Review Comments	Jan, 2007	Brown et al.
Submit Final to I&M PACN	Jan, 2007	Brown & Daniel

Brown et al. (1999) concluded that one of the most reliable and cost effective techniques to monitor change in composition of the marine benthos (Objective 1a) was photo-quadrats along a transect line. This technique addressed multiple spatial scales, had sufficient statistical power to detect moderately small changes (10% change), and provided a permanent record of the coral reef community. The presence of disease (Objective 2c) can also be measured with photo-quadrats. However, use of photo-quadrats must occur simultaneously with some in field data recording, as photo-quadrats alone cannot adequately characterize changes in the benthic community. These methods will require modification (e.g., specific transect length, necessary number of photos, etc.) to account for the variability among PACN parks in marine benthic species diversity and physical reef topography. Standard methods exist to measure rugosity (e.g., chain method), recruitment (e.g., settling plates, *in situ* assessments, etc.), and growth and survival (e.g., *in situ* coral tagging, alizarin dye, etc.). Where appropriate, the sampling design will collocate the monitoring for each objective. The specific sample design with incorporate guidance provided by the I&M Program (Fancy 2000). A small set of methodologies (e.g. four) will need to be modified to address this vital sign and because of their interrelated nature, they can be developed, tested, and implemented in parallel.

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Development Schedule, Budget, and Expected Interim Products: This monitoring protocol will require 18 months to complete. A total budget of $146,500 is requested from I&M.

Budget Table FY05

	FY2005 NPS I&M funds	FY2005 NPS funds (in kind)	FY2005 HPI-CESU Agreement
Personnel			
Biological Tech. (Full time, 1 year)			$30,600
Biological Tech benefits (25%)			$7,700
Marine Protocol Facilitator (Full time, 6 months)			$18,000
Protocol Facilitator benefits (25%)			$4,500
1 x Ecologist (GS-11, 0.4 FTE, w/ 33% benefits, 3 months)		$6,000	
Science Advisor (GS-13, 0.4 FTE, w/ 33% benefits, 3 months)		$15,000	
1 x Ecologist (GS-11, 0.2 FTE, w/ 33% benefits, 3 months)		$3,000	
Travel			
1 x Hawaii-WAPA	$3,335.17		
Materials & Supplies			
Office supplies and misc. field supplies for PIs			$900
Misc. support supplies		$3,000	
Equipment			
Subtotal	$3,335.17	$27,000.00	$61,700.00

Overhead (17.5%)	NA	NA	$10,800
TOTAL (Subtotal + Overhead)	**$3,335.17**	**$27,000.00**	**$72,500.00**

Budget Table FY06

	FY2006 NPS I&M funds	FY2006 NPS funds (in kind)	FY2006 HPI-CESU Agreement
Personnel			
Biological Tech. (full time, 6 months; includes 10% pay increase)			$16,900
Biological Tech benefits (~25%)			$4,300
Marine Protocol Facilitator (Full time, 6 months; include 10% pay increase)			$19,900
Protocol Facilitator benefits (~25%)			$5,000
1 x Ecologist (GS-11, 0.4 FTE, w/ 33% benefits, 12 months)		$24,000	
Science Advisor (GS-13, 0.4 FTE, w/ 33% benefits, 12 months)		$60,000	
1 x Ecologist (GS-11, 0.2 FTE, w/ 33% benefits, 12 months)		$12,000	
Travel			
Protocol Development Workshop (Oct..31-Nov. 6) (7 days, HAVO). Includes: E. Brown (airfare: $400, hotel (6 x $105), per diem (6 x $80), rental car (6 x $32)). L. Basch (airfare: $200, hotel (6 x $105), per diem (6 x $80), rental car (6 x $32)). D. Minton (airfare: $2,000, hotel (6 x $105), per diem (6 x $80), rental car (6 x $32)). R. Daniels (airfare: $200, hotel (6 x $80), per diem (6 x $30)). P. Craig (airfare: $2,000, hotel (6 x $105), per diem (6 x $80), rental car (6 x $32)). Conference Room Rental (7 x $250) Misc. Expenses (printing, taxes, etc) $747	$13,116		
Misc. Travel for I&M Marine Protocol Facilitator			$2,825
Materials & Supplies			
Equipment			
Subtotal	$13,116.00	$96,000.00	$48,925.00
Overhead (17.5%)	NA	NA	8,575
TOTAL (Subtotal + Overhead)	**$13,116.00**	**$96,000.00**	**$57,500.00**

Total FY05 funding requested from PACN I&M (I&M + CESU Agreement): $75,835.17
Total FY06 funding requested from PACN I&M (I&M + CESU Agreement): $70,616

TOTAL REQUESTED I&M FUNDS: $146,500

Justification: Only 15 months of budget has been requested for an 18 month project. The final three months of this project will entail protocol review and modification and will not require I&M funding. This level protocol development is justified because we cannot simple modify the USVI coral methods and use them here. These methods, while very good for USVI (and maybe some of the HI parks), will not work at many PACN parks because the environmental conditions will not allow it). We can use their methods as guidelines as a starting point. Additionally, much of the field work investment in this PD is to obtain the information necessary to create a statistically-rigorous sampling design (e.g. need good measures of natural benthic variability). This takes time in water which is expensive.

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MARINE FISH

Parks where protocol will be implemented:
Phase 1: WAPA, NPSA, KALA, and KAHO
Phase 2 (pending funding): AMME, HALE, ALKA, PUHE, PUHO, and HAVO

Justification/Issues being addressed:
Fish are a major component of the coral reef ecosystem, potentially numbering 500-900 species in PACN parks depending on geographic location (Myers 1999). This highly diverse assemblage of carnivores, planktivores, herbivores and detritovores serve a variety of ecological functions that affect ecosystem structure, productivity and sustainability (e.g., Sale 1991, Hixon 1997). Fish assemblages or selected species can also act as indicators of general reef health and provide a warning of environmental stress and potential ecosystem change (e.g., Friedlander and DeMartini 2002). Additionally, fish within the parks are harvested in traditional, subsistence, artisanal and recreational fisheries (e.g., Craig et al. 2004) which may affect the species composition, abundance and size of targeted species. Fishing is increasingly being recognized as the principal threat to Pacific coral reefs and other marine ecosystems worldwide (e.g., Dayton 1998, Friedlander and DeMartini 2002 Birkeland 2004, Hutchings and Reynolds 2004). In this respect, it is highly probable that most of the Pacific Islands parks can be categorized as "impaired" to "seriously impaired" in terms of their fish communities. Marine fish ranked 9th in implementation rank as a network Vital Sign. While the harvest of fish is addressed in a separate complementary (fisheries-dependent) protocol, data collected here will contribute to the overall analyses by providing an in-water (fisheries-independent) assessment of the size and abundance of harvested species within park waters.

Specific Monitoring Questions and Objectives to be Addressed by the Protocol:

Question 1: For coral reef fishes, what are long-term trends in the abundance and biomass of key reef slope species of ecological, cultural or harvest significance at selected sites along an isobath of 10-20 m depth?

Objective 1**:** Annually determine the density and biomass of the defined component of the reef fish assemblage at randomly selected sites along an isobath of 10-20 m depth.
Justification: Long-term changes in the abundance and biomass of fish assemblages can often be correlated with specific stressors or drivers. For example, declines in size and abundance of harvested species are often associated with overfishing. Reef fish diversity and biomass also correlate with the structural complexity of reef habitats; a declining trend in habitat complexity is known to be associated with declines in the fish community. Moreover, many reef fishes are either large apex predators or major herbivores whose trends in abundance can have ecologically and statistically significant impacts on coral reef ecosystems and the dynamics of major system components; e.g., declines in herbivorous fishes could result in increased growth and benthic cover of native or invasive algae which can out-compete and overgrow corals, leading to associated declines in coral health, reef structure and ecosystem resiliency. Note that this objective focuses on the visible diurnal component of the coral reef fish fauna, rather than on small, cryptic or nocturnal species (while some of the latter are of ecological or management importance, the additional effort and time required to sample these fish is not usually justifiable

in reef fish monitoring efforts; many of these fish are being/will be recorded in reef fish inventories, and will be adaptively monitored only if compelling resource trends [e.g., precipitous declines] or management needs arise).

Basic Approach:
The methodology to monitor coral reef fish has been actively developed over the past 25 years, therefore this is a fairly straight-forward Vital Sign for which there are a number of existing protocols (e.g., Bohnsack and Bannerot 1986, Rogers et al. 1994, English et al. 1997, Samoilys 1997, Sweatman et al. 1998, AGRRA 2000, Hill and Wilkinson 2004). The primary survey techniques used to monitor coral reef fish consist of visual counts of fish in a sample unit, either along belt transects or in stationary plot (or point) counts, both of which are conducted by trained scientific divers. The exact transect or plot dimensions are tailored to the specific locations or habitats being surveyed as well as to the behaviors of the fishes being surveyed. Belt transects are typically 2-5 m wide and 25-50 m long; circular plots are usually up to about 7-m in diameter and are observed over a 10-15 min period. The number of replicates needed for each method requires site-specific trials to determine the statistically optimal sample size (e.g., Friedlander et al. 1999).

Initial tasks for development of this protocol will be to review and summarize existing reef fish monitoring methods, evaluate the sizable literature comparing specific techniques, assess their applicability to our current monitoring needs, tentatively select, and test methods. At the same time, a statistically rigorous sampling design will be developed and a key part of this protocol will be field testing the proposed methods and sampling design at several of the widely separated parks in our network. American Samoa, Guam, and Hawaii, which are separated by thousands of miles of ocean, have different coral reef fish communities, thus it cannot be assumed that one sampling technique or design will work equally well at all sites. The NPS lead and PIs will therefore need to travel to parks to help test the adequacy of any park-specific sample designs.

Sample Design: Sampling sites for marine fish will be selected within parks that are co-located in the same sampling frame with protocols for monitoring benthic community and water quality. These sites will be randomly chosen at the onset within the strata of interest (e.g., 10-20 m depth range and hard substratum) and then subsequently monitored on an annual basis. The design for temporal frequency of sampling at the sites will coincide with the other protocols listed above and will likely utilize a split panel sampling design in which some sites will be monitored every year within a park while other sites will be sampled on a rotating schedule at intervals of 3-5 years. Periodically, a few randomly chosen sites within each park will be sampled more intensively to develop a comprehensive picture of the entire fish assemblage for biodiversity assessment.

Surveys are generally conducted at a standard depth, usually between 10-20 m, because diving time in deeper waters is significantly reduced, and reef fish and their habitat are often less abundant. Shallower sites can be included, depending on the monitoring question(s), fish and habitat distributions, and park-specific needs; however, addition of shallower sites increases time, effort and cost of monitoring. Sampling at an annual interval may be adequate to document changes in fish abundance and biomass over time, although more frequent sampling may be required in some park-specific situations.

These non-destructive techniques focus on one major component of the coral reef fish community -- the diurnal or day-active fish species that are highly visible due to their typically bright coloration and generally large size and to good visibility underwater. It is recognized that this approach does not document small or cryptic fish (which might require time-consuming or destructive sampling) or nocturnal fish (because of increased logistical and safety concerns involved in nighttime scuba work). Within these limits and program goals, divers either identify, or count and estimate size of all species observed or particular species of interest, such as those harvested or of cultural or ecological importance.

A visual estimate of fish size is an important component of these surveys for several reasons. First, lengths allow a conversion from fish numbers to biomass by using established length-weight relationships. Second, lengths are often a useful indicator of fishing pressure or population dynamics, e.g., a trend of decreasing sizes may indicate overfishing, or recruitment year classes. Third, there is a strong positive correlation between fish size and fecundity (reproductive potential) which, along with recruitment success, is important in projecting future population trends in many species, and adapting management accordingly. Observer's accuracy at estimating fish sizes must be periodically inter-calibrated to avoid sampling biases.

Data Analysis: Spatial analysis of fish assemblage data will utilize standard univariate (e.g., general linear models) and multivariate (e.g., multidimensional scaling) procedures to examine the influence of factors (e.g., management regime) structuring fish communities (e.g., Friedlander et al., 2003). Temporal data sets will utilize repeated measures ANOVA and regression analysis to detect changes in the fish assemblages. Trend analysis using route regression or period mean regression will be employed when analyzing fish data sets with other data sets (e.g., benthic marine community parameters) that are co-located and may be sampled at different frequencies.

Investigators and NPS Lead:
As several individuals will participate in the preparation of this protocol, the role of each participant has been identified below. Any changes in key participants or their roles will be subject to prior approval and will be specified via modification to the study plan. See Table 2 for a summary of responsibilities.

PIs: Jim Beets, Marine Ecologist, University of HI, 808-933-3493, beets@hawaii.edu
Alan Friedlander, Marine Ecologist, NOS-NOAA, University of HI – Hawaii Institute of Marine Biology, afriedlander@oceanicinstitute.org
NPS Lead: Peter Craig, Marine Ecologist-NPS, 684-633-7082, Peter_Craig@nps.gov
Eric Brown, Marine Ecologist-NPS, 808-567-6802 x40, Eric_Brown@nps.gov

Development Schedule, Budget, and Expected Interim Products:

Table 1. Timeline for developing the Marine Fish Protocol (Phase 1).																																							5-May-06
		2005					2006												2007												2008								
Task		A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S
Protocol study plan																																							
	site visits	x																																					
	literature review	x	x	x																																			
	statistician meeting				x																																		
	submit for peer review														x																								
	finalize																x																						
Study design																																							
	statistical analysis					x							x																										
	PI draft study design														x																								
	I&M review															x																							
	consensus meeting																x																						
	receive I&M comments																	x																					
	Chapt. 2 & related SOP																		x																				
	finalize																			x																			
Database preparation																																							
	initiate design																		x																				
	design completed																					x																	
	submit to I&M																						x																
	finalize																										x												
Field testing																																							
	preliminary testing																x																						
	NPSA testing																		x	x	x																		
	WAPA testing																							x	x	x													
	KALA, KAHO testing																								x	x	x												
Protocol development																																							
	protocol outline														x																								
	initiate text															x																							
	SOPs completed																					x																	
	receive I&M comments																							x															
	final draft																									x													
	receive I&M comments																											x											
	submit for peer review																														x								
	receive peer comments																																	x					
	submit final to I&M																																			x			
	finalize & wrap-up																																						x

Budget summary tables follow for FY05-FY08:

Table 2. *FY2005 costs. NPSA FY05 funds will be used by the PI/PD over a multi-year period.*

	FY2005 NPS I&M funds	FY2005 NPS funds (in kind)	FY2005 HPI-CESU Agreement (from NPSA)
Personnel	0	25,450	46,809*
PI Jim Beets (2.5 mo)*			20,795*
PD Alan Friedlander (2.4 mo)*			20,014*
UH student research assistant, 3.8 mo at $9.24 (includes fringe)			6,000*
NPS Lead (GS-11, 3 mo)		19,750	
Science Advisor (GS-13, 0.5 mo)		5,700	
Travel		5,000	
NPS Lead: 1 x NPSA-Hawaii-Guam-CNMI		5,000	
Subtotal			46,809
Overhead (17.5%)	NA	NA	8,191
TOTAL	0	$30,450	$55,000 (from NPSA)

*Over multi-year period.
Total FY05 funding requested from PACN I&M: $0

Table 3. *FY2006 costs.*

	FY2006 NPS I&M funds	FY2006 NPS funds (in kind)	FY2006 HPI-CESU Agreement
Personnel	36,900	49,700	0*
PI Jim Beets (1.0 mo)*			0*
PD Alan Friedlander (1.0 mo)*			0*
UH student research assistant (0.5 mo at $9.24 including fringe benefits)			0*
Ecologist (GS-11, 4 mo), NPSA		26,700	
Ecologist (GS-11, 1 mo), KALA		6,500	
Ecologist (GS-9, 2 mo), NPSA		7,500	
Science Advisor (GS-13, 0.5 mo)		5,700	
Bio Tech (GS-5, 1 mo), NPSA		3,300	
Data Manager (GS-11, 3 mo)			0**
Facilitator (R. Daniel, 9 mo)	36,900		
Travel	12,400		
PI/PD: Hawaii-NPSA (1 wk), Hawaii-WAPA (1 wk), 4 x Hawaii-Kona/Hilo.	12,400		

Materials & Supplies	4,100		
Field/office supplies, air fills, misc.	2,000		
Boat charter (6 days at $350)	2,100		
Subtotal	53,400	49,700	
Overhead (17.5%)	9,345	NA	
TOTAL	$62,745	$49,700	0*

* PI/PD carryover from FY05.
** Covered in marine benthic community protocol.

Table 4. *FY2007 costs.*

	FY2007 NPS I&M funds	FY2007 NPS funds (in kind)	FY2007 HPI-CESU Agreement
Personnel	0*	49,900	0*
PI Jim Beets (1.5 mo)*			0*
PD Alan Friedlander (1.5 mo)*			0*
UH student research assistant (2.5 mo at $9.24 including fringe benefits)			0*
Ecologist (GS-11, 4 mo), NPSA		26,700	
Ecologist (GS-11, 1 mo), KALA		6,700	
Ecologist (GS-9, 2 mo), NPSA		7,500	
Science Advisor (GS-13, 0.5 mo)		5,700	
Bio Tech (GS-5, 1 mo), NPSA		3,300	
Data Manager (GS-11, 3 mo)			0**
Facilitator (R. Daniel)	0*		
Travel	9,600		
E.Brown: 2 x HNL-Kona/Hilo	2,400		
NPS Lead: 1 x NPSA-Hawaii	3,600		
P.Brown: 1 x NPSA-Hawaii	3,600		
Materials & Supplies	2,000		
Supplies, air fills, misc.	2,000		
Subtotal	11,600	49,900	
Overhead (17.5%)	2,030	NA	
TOTAL	$13,630	$49,900	

* PI/PD carryover from FY06.
** Covered in benthic marine community protocol.

__Table 5.__ FY2008 costs.

	FY2008 NPS I&M funds	FY2008 NPS funds (in kind)	FY2008 HPI-CESU Agreement
Personnel	18,440	13,300	
PI Jim Beets (0.25 mo)	2,280		
PD Alan Friedlander (0.25 mo)	2,280		
UH student research assistant (1.0 mo at $9.24 including fringe benefits)	1,580		
Ecologist (GS-11, 1 mo)		7,100	
Science Advisor (GS-13, 0.5 mo)		5,700	
Facilitator (R. Daniel, 3 mo)	12,300		
Subtotal	18,440	13,300	
Overhead (17.5%)	3,227	NA	
TOTAL	$21,667	$13,300	

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FRESHWATER ANIMAL COMMUNITIES

Prepared by: Anne Brasher

Parks where protocol will be implemented: WAPA, NPSA, KALA, HALE, and ALKA

Justification/issues being addressed:
A diverse array of freshwater and brackish habitats are found in PACN parks, including streams, anchialine pools, man-made coastal fishponds, a saline lake, and subalpine ponds and bogs (though several of these ecosystem types are mixohaline, the term "freshwater" is used in order to differentiate this Vital Sign from marine Vital Signs in the network). Freshwater ecosystems are internationally considered to be among the world's most vulnerable (UNEP 2004). Due to the isolation of the Pacific Islands, there is a high level of endemicity in the small number of native freshwater species within each of these habitats. Additionally, several freshwater animals are listed as candidate endangered species or species of concern. Throughout the region, exotic species introductions and habitat destruction are significant threats to native animal populations, and the PACN parks protect some of their last remaining habitats. For these reasons, the PACN Freshwater Animal Communities Vital Sign was ranked 7th in priority for implementation.

Specific monitoring questions and objectives to be addressed by the protocol:
The goal of this protocol is to assess the composition, status, and trends of aquatic fish and invertebrate communities in freshwater and mixohaline habitats in the PACN.

Monitoring questions:

- What are long-term trends in community composition, population distribution, and abundance of freshwater fish and invertebrates (including snails, crustaceans, and water-associated insects)?
- How do park management activities (i.e., those that impact aquatic ecosystems) affect the community composition and abundance of freshwater fish and invertebrates (including snails, crustaceans, and water-associated insects)?

Monitoring objectives:

1a. Determine long-term trends in the composition and diversity of fish and invertebrates in selected freshwater and mixohaline communities.
1b. Determine trends in the distribution and abundance of fish and invertebrate populations in selected stream and lentic habitats.

Justification: Species included in this protocol include native and exotic fish, aquatic and semiaquatic snails, and crustaceans. A relatively small number of native and exotic freshwater fish and macroinvertebrate species are present in any one habitat type in the PACN, though species present will vary in different island groups.

Freshwater resources in several PACN parks have been minimally inventoried, and representative monitoring sites at these parks will be selected as part of protocol development. Specific aquatic habitats which will potentially be monitored include: Waikolu Stream (KALA), Kipahulu district streams (HALE), and selected streams in NPSA. Additional streams in AMME, WAPA, KALA, HALE, PUHE , and HAVO may also be selected for monitoring after site evaluation.

2. Improve understanding of relationships between freshwater and brackish water animal communities and their habitat by correlating physical and chemical habitat measures with changes in distribution and abundance of fish and invertebrates.

Justification: This objective provides information about the effects of management activities on physical habitat (NRCS 2001). This information is critical in determining the effects of habitat change on aquatic animal communities. Monitoring will also be coordinated with Water Quality Vital Sign monitoring to link water quality monitoring data to physical habitat data.

Basic approach:

Several sampling methods have been established for animal communities in PACN streams, and will be evaluated for this protocol. These include: 1) visual surveys of gobies, snails, and crustaceans made while snorkeling (Baker & Foster 1992, Brasher 1996), 2) trapping of crustaceans, and 3) electrofishing. SOPs will be created for each sampling method, along with standard criteria to be used determine which method to use at each site. Physical habitat assessment methods will be identified for monitoring sites concurrently with biological sampling (Fitzpatrick et al. 1998). The following measures are suggested by Hodges (1994) and Brasher (1997):

- At each sampling station: elevation, canopy cover, distance from stream mouth, discharge, stream width, and dominant habitat type (riffle, boulder riffle, pool, run, edgewater).
- In each quadrat: dominant habitat type, distance of quadrat from edge of stream, substrate composition (% cover of sand, gravel, cobbles, rocks, boulders, or bedrock), rugosity (measured by draping a chain diagonally across the quadrat), percent detrital cover, depth (in center of quadrat and at the deepest point), and water velocity (in center of quadrat).
- At the location of each organism: depth, substrate composition, and water velocity.

Chemical measures of water quality, to be coordinated with the measures required by the Water Quality protocol, will include the NPS core water quality parameters: temperature, pH, DO, conductivity, TP, TN, chl *a*, and turbidity.

Visual snorkel surveys:

Visual snorkel surveys are a well-established sampling method for native fish, snails, and crustaceans in Hawaii. Their utility needs to be evaluated in NPSA (and WAPA, if this monitoring will be done there) and compared with that of electrofishing. Reasons for this are stream water quality (i.e., visibility and health of observers) and habit of organisms. Native Hawaiian gobies are benthic and tend to sink when stunned, whereas more mobile pelagic fish species are better observed using electrofishing.

The sampling area at each station is fixed at 100 m^2 for snails and 300 m^2 for shrimp and gobies. The lengths of stream to be sampled at each station for snails and shrimp/gobies are determined by dividing 100 and 300 meters respectively by the bank to bank width. Ten 625 cm^2 and $1m^2$ quadrats (for snails and shrimp/fish, respectively) are surveyed randomly in the station by snorklers. Quadrat placement is generated by using a Cartesian coordinate system.

The following measures are taken:

- For fish: density and size class (<0.5”, 0.5”,…,>9” in 0.5” increments) in each quadrat
- For shrimp: density in each quadrat, size class in a netted sample of at least 30 individuals in each stream
- For snails: density of individuals and egg cases and size class distribution of individuals in each quadrat (for egg cases, ¼ of the quadrat is surveyed)

Crustacean trapping & electrofishing:
Non-destructive crustacean trapping has been used to sample the non-native carnivorous/detritivorous prawn *Macrobrachium lar* in Hawaiian streams. Visual surveys are preferred to trapping for native herbivorous/detritivorous Hawaiian shrimp (Hodges 1994). Trapping, visual surveys, and other macroinvertebrate sampling methods should be evaluated in the West Pacific parks, which have a higher diversity of crustacean fauna. Trapping surveys are a three-day process involving at least 2 people. Wire mesh traps baited with dog or cat food are placed in the stream for a specified amount of time, and individuals later removed. Measures to be taken are: number of individuals and size class distribution.
Electrofishing may be conducted in preference to visual survey methods in cases where stream condition does not permit snorkeling. Standard methods for electrofishing are available and will be adapted into a SOP for PACN streams.

Principal investigators and NPS lead:
PI: Anne Brasher, Aquatic Ecologist, USGS-WRD, 435-259-3866, abrasher@usgs.gov
NPS Lead: Tahzay Jones, Aquatic Ecologist-PACN, 808-985-6188, Tahzay_Jones@nps.gov

Work Schedule:

Table 2. *Work schedule.*

Task	Task description	Completion	Interim products
1	Finalize study plan	15 August 2005	
2	Compile methods, and produce tentative sample design recommendations-	30 September 2005	
3	Review and summarize existing data	30 March 2006	
4	Rough draft of protocol to PACN for review	30 Sept. 2006	
5	Visit individual park units, site evaluations. Field test methods. Monitoring site selection.	30 December 2006	Draft field methodology & site evaluation report.
6	Develop sampling design, finalize analytical, monitoring, and reporting methods.	30 March 2007	Draft protocol: includes sampling design and analytical, monitoring, and reporting methods.
7	Peer review and finalize protocol.	30 Sept. 2007	Draft final protocol.
8	Revisions based on peer review comments	1 Jan. – 30 May 2008	Final Protocol

Budget and Staff:
A total of $110,000 will be needed to develop the freshwater animal community monitoring protocol. The work will be accomplished by the USGS Utah Water Science Center in cooperation with the NPS PACN I&M Program. A cost breakdown is provided in table 3.

Table 3. *USGS-Utah and HPI-CESU agreements are intended as multi-year, for period FY2005-FY2009.*

	Previous USGS-Utah FY2005 USGS Interagency Agreement	USGS-Utah FY2006 USGS Interagency Agreement	Subsequent anticipated-needed funding to complete protocol
Personnel (PI)	**$ 8,000**	**$ 8,500**	**$13,000**
Personnel (Student)	**$ 4,500**	**$ 3,500**	**$ 5,000**
Travel	**$ 0**	**$ 5,200**	**$ 6,400**
Material & Supplies	**$ 750**	**$ 1,300**	**$ 2,000**
IT & Information Management	**$ 1,800**	**$ 2,300**	**$ 3,300**
Science Support and Project Management	**$ 2,100**	**$ 3,400**	**$ 4,900**
Facilities Support	**$ 1,600**	**$ 2,500**	**$ 3,500**
Subtotal	**$18,750**	**$26,700**	**$38,100**
Overhead	**$ 6,250**	**$ 8,400**	**$11,900**
TOTAL	**$25,000**	**$35,100**	**$50,000**

This budget does not include in-kind matching funds to be provided by USGS or overhead costs.

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FOCAL TERRESTRIAL PLANT COMMUNITIES

Prepared by: Jim Jacobi and Alison Ainsworth (last modified 8/10/06)

Protocol: Focal Terrestrial Plant Species and Communities: Community Composition and Structure, Species Distribution and Abundance

Parks Where Protocol May be Implemented: HALE, HAVO, KAHO, KALA, NPSA, WAPA, AMME

Justification/Issues being addressed: Focal terrestrial plant species and communities were ranked by the Pacific Area Network (PACN) as the number one vital sign for implementation. This monitoring protocol addresses these issues at both the community and species level.

The central reasons for monitoring terrestrial plant communities are: (a) they are key indicators of ecosystem health (Peet 1992), (b) these communities reflect the dynamic between invasive plant species and native species (Walker and Smith 1996), and (c) plant communities can indicate management needs and management effectiveness. Invasive species are the overriding threat and biological resource management issue in most of the PACN Parks. Habitat fragmentation, climate change, and catastrophic disturbance such as hurricanes and fire may also alter the composition and structure of these Island plant communities (D'Antonio and Vitousek 1992, Cuddihy and Stone 1990). Changes in plant communities may affect the desired future condition in the vegetation element of historical landscapes.

Monitoring key characteristics (e.g. species composition, community structure) of focal plant communities informs managers of changing conditions that may require management action and provides feedback on the effectiveness of those actions in protecting important plant community resources. To date, some parks in the network have conducted a limited number of monitoring studies in a small fraction of their plant communities. However, this has often been associated with the control of alien ungulates, alien plants, or during restoration efforts. PACN National Parks have tentatively identified their focal plant communities in Phase II of the monitoring plan, based on relative intactness, high species diversity, and prevalence across the different parks. These focal plant communities include: rain forest/cloud forest (HAVO, HALE, NPSA, and KALA), and subalpine/alpine communities (HAVO, HALE). The network parks also identified plant communities unique to their areas (e.g. limestone forest at WAPA, diverse mesic forest at HALE and HAVO, summit scrub at NPSA, lava flow/kipuka mosaics at HAVO , selected coastal communities (KAHO, HAVO), montane bogs at HALE), wetland and mangrove communities at AMME, and selected intensively managed communities to be considered for monitoring.

At the species level, Threatened and Endangered (T&E) plants are recognized as important elements to conserve in most PACN Park units. Parks are mandated, under the federal Endangered Species Act, to monitor conditions of endangered species and implement recovery activities as needed. Other rare plants may be indicators of changes that impact entire communities; their decline may serve as an early warning of ecosystem degradation. The larger parks of the PACN support a high number of listed Threatened and Endangered plant species and “Species of Concern” (SOC). The SOC category includes recognized rare species that have not formally been listed by the USFWS as endangered. Other native plant species are rare or depleted within the parks, but may not be rare throughout their range. In addition to rare species, most parks have focal plant species that are necessary habitat elements for rare invertebrates or important vertebrate species; other plants may be considered focal because of their cultural values or importance in remnant native communities. The number of T & E, rare, and focal plant species within a park relates primarily to its size and range of habitat types. Based on biodiversity and number of rare species, the PACN parks fall into three groups: parks that have high biodiversity and many rare plant species, parks that have low native plant diversity and few rare and focal species, and the two West and South Pacific Parks within PACN (Tables 1 – 2).

Table 1. *Number of T&E, candidate, species of concern (SOC), rare, and potential focal species for the three large Hawaiian Parks that have high biodiversity and many rare plant species.*

Park	T&E Spp.	Candidate Spp.	SOC Spp.	Rare Spp.	Focal Spp.
HALE	16 (6 extirp.)	10 (3 extirp.)	15 (1 extirp.)	Ca. 30	Ca. 30
HAVO	18 (5 extirp.)	4 (1 extirp.)	18 (4 extirp.)	Ca. 40	Ca. 30
KALA	>30 (15 extirp.)	5 (2 extirp.)	41 (10 extirp.)	?	?

The number of extirpated species is in parentheses, but it is possible that some of these may be rediscovered with additional field work. All three parks have suites of focal native plants that act as hosts and breeding sites for endemic groups of insects, such as *Drosophila* pomace flies (e.g. *Clermontia* spp., *Cheirodendron trigynum*), *Megalagrion* damsel flies (*Astelia menziesiana*, *Freycinetia arborea*), and *Plagithmysus* beetles (several endemic trees and shrubs).

Table 2. *Number of T&E, candidate, SOC, rare, and potential focal species for the four small Pacific Island Parks that have low native plant diversity and few rare and focal species.*

Park	T&E Spp.	Candidate Spp.	SOC Spp.	Rare Spp.	Focal Spp.
AMME	0	0	0	1	<10?
KAHO	0	1	2	9	10-15
PUHE	3 (planted)	0	1 (planted)	1	<10?
PUHO	1 (planted)	0	1	5	<10?

At NPSA, rare flying foxes (*Pteropus* spp.) and fruit-doves depend on a suite of fruit-bearing trees; these are focal plant species. At WAPA, *Elaeocarpus joga* and *Artocarpus mariannensis* trees are critical elements for any re-introduction efforts of the Marianas crow (*Corvus kubaryi*). Native cycads (*Cycas circinalis*) are an important food source for the endangered Mariana fruit bat (*Pteropus mariannus*). Native trees and shrubs restricted to limestone forests and savanna are also focal species for WAPA.

Monitoring is needed for managers to evaluate the status of rare plant species within the parks and to develop management strategies adequate for their protection. Protocols for rare plant surveys and monitoring have been developed by several agencies in Hawai`i, including NPS. No comprehensive and consistent monitoring scheme has been developed for Network Parks in Hawai`i and the Pacific.

Specific Monitoring Questions and Objectives to be Addressed by the Protocol:

Question 1: What are the long term trends in plant community composition and structure in focal communities identified by PACN Network parks?

Objective 1: Determine changes at one to ten year intervals in vascular plant species presence/absence, cover, and density (woody species density by height or diameter classes) in focal plant communities identified by the PACN network.

Question 2: What are the status and long-term trends in distribution, abundance, and demography of endangered, rare, and other focal native vascular plant species (e.g., species with cultural significance) in the PACN Network parks?

Objective 2a: Compile species lists and location data from previous plant inventories, existing databases, and ongoing surveys and mapping projects in PACN parks.

Objective 2b: Determine changes at one to five year intervals in the distribution and abundance of selected rare, threatened, endangered, and other focal plant species within selected native plant communities of seven PACN parks.

Objective 2c: Determine changes at one to five year intervals in the stand structure (size class distribution) of focal plant species populations within PACN parks.

Objective 2d: Examine if changes in the abundance and stand structure of focal plant species populations are related to management activities (e.g., nonnative plant and animal control in Special Ecological Areas, species reintroductions, etc.).

Justification: Long-term vegetation monitoring is essential to determine plant community health, ecosystem stability, and the effects of management activities. National Parks are important as controls in environmental monitoring systems that include similar ecosystems highly altered by man. Changes in species composition and community or stand structure are indicators of changing physical (e.g., soil, hydrology, nutrient processes) and biological conditions (e.g., invasive plants, animals, insects, and disease). Because basic plant community level parameters such as cover and density are repeatable over time analysis of trends can generate a predictive model for determining the future outcomes of plants, communities, and ecosystems. These models enable managers to modify management practices to ensure the long term persistence of native ecosystems.

PACN parks provide habitat for significant numbers of threatened and endangered plant species, as well as candidate endangered plants and species of concern. Other species are unnaturally rare because of past land use and ongoing disturbance from nonnative species. Certain plants with cultural significance may also be appropriate for long-term monitoring. Four types of native-dominated plant communities, along with smaller communities unique to individual parks (e.g. limestone forest), support most of the endangered and rare plant populations within PACN parks. Without current data on the distribution, abundance, and population trends of these T & E and rare species, their status within the parks cannot be evaluated and conservation priorities cannot be properly assigned. Data are also needed to determine whether current management actions are adequate to protect and maintain rare plant populations within the parks.

Basic Approach:
The methodology for developing the protocol and SOPs for monitoring focal terrestrial plant communities will involve the following steps: (1) Review and evaluate standard protocols for plant community monitoring so pertinent sampling and analysis methodologies may be incorporated into this community monitoring protocol. (2) Establish potential locations of permanent plots randomly along systematic transects, with the first transect established randomly. (3) Post-stratify to determine sampling adequacy in focal communities. (4) Establish vegetation plots optimized for particular types of plant communities (e.g., smaller plot size for grassland communities; larger plots for forest communities), and measure species composition and community structure in these vegetation plots. (5) Determine the number of plots to be sampled in each community by conducting a power or simulation analysis utilizing variance data obtained from existing data or from pilot studies where needed. A tentative level of confidence for most communities is the monitoring effort should detect, at least, a 20% change in community parameters. (6) Develop recommendations for sampling and confidence levels for small or highly variable communities. In these cases the total number of plots sampled will not exceed 30. (7) Prepare a handbook with SOPs for monitoring plant communities. This handbook will include methods specific to monitoring focal plant communities, but also provide recommended standards for data collection and analysis techniques. The handbook will assist parks in developing strategies for monitoring plant communities that are of local importance but are not included on the PACN focal plant community list, as well as facilitate sharing of monitoring data. An example of a standardized monitoring handbook designed to address different community types (e.g., forest, shrubland, grassland) and different management objectives is the "The Fire Monitoring Handbook" developed by the National Park Service (2000).

The methodology for identifying, selecting, and monitoring rare and focal plant species and populations will include several steps. (1) Compile data from previous plant inventories, existing databases, and ongoing surveys and mapping projects in PACN parks. A primary source of this information will be the NPSpecies database. New data gathered during this study will also be entered into NPSpecies. (2) Prepare a geodatabase containing all plant location information (both point and polygon data). (3) Confirm the presence and status of rare and selected focal species populations in the field. (4) For area or polygon data, generate random locations within all or a subset of polygons to verify presence of the rare or focal plant species. (5) After consultation with park managers, select the rare and focal plant species and populations for long-term monitoring efforts. Focal plant species will be selected for monitoring by several criteria which include: habitat type, degree and urgency of threat, accessibility, feasibility of management, and cultural significance. (6) Determine plot size and shape, and data to be collected from monitoring plots. (7) Determine sample size and frequency for sampling.

For those parks or units where the distributions of T & E and rare plant species are unknown, new rare plant surveys must be carried out to locate populations prior to implementation of monitoring.

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Development Schedule and Budget:

Jim Jacobi and Linda Pratt are also the PIs for the established invasive plant species protocol and will work on both of these concurrently. The draft of the focal plant communities and species protocol will be completed in January 2007 and submitted for peer review. Final revisions of the protocol will be completed by March 31, 2007.

FY2006

June 2006

- Hire Botanical Specialist (RCUH, GS-9 equivalent) as lead person for protocol development. This person will be coordinating the development of two related protocols: Focal Plant Communities and Species, and Established Invasive Plant Species.
- Complete interagency agreement based on draft of study plan
- Complete study plan and submit for NPS peer review

July to August 2006

- Draft sampling design (i.e., delineate areas, determine necessary sample sizes, determine accessibility, select sampling sites, prepare Minimum Tool Analysis for applicable park units).
- Select and prioritize RTE and focal plant species in each park
- Complete field visits to PUHO, PUHE, and KAHO.

September 2006

- Complete field visits to WAPA and AMME.
- Prepare and submit annual progress report

FY2007

October 2006

- Refine SOPs and sampling methodologies for this protocol.
- Complete field visits to NPSA, HALE, KALA, and HAVO.

November – December 2006

- Prepare protocol documentation and SOPs
- Compile all new data into protocol database

January 2007

- Submit complete draft of protocol and supporting documents and datasets for peer review

March 2007

- Complete revisions of protocol based on review comments and submit to PACN I&M Coordinator

- Provide all datasets, GIS themes, etc., with FGDC compliant metadata to PACN I&M Coordinator
- Submit final project completion report

Budget

FY 2005 costs.

	FY 2005 USGS IAA	FY 2005 NPS Funds	FY 2005 HPI-CESU Agreement	Total Funds
Personnel			44,450	44,450
Travel			4,550	4,550
Materials & Supplies			1,724	1,724
Equipment			5,000	5,000
Subtotal			55,724	55,724
Indirect Costs			9,752	9,752
TOTALS			**65,476**	**65,476**

Indirect Cost Amount	*15%*	*0%*	*17.5%*	

FY 2006 costs.

	FY 2006 USGS IAA	FY 2006 NPS Funds	FY 2006 HPI-CESU Agreement	Total Funds
Personnel			11,500	11,500
Travel	10,557	2,186	428	13,171
Materials & Supplies				-
Equipment			591	591
Subtotal	10,557	2,186	12,519	25,262
Indirect Costs	1,584	-	2,191	3,774
TOTAL	**12,141**	**2,186**	**14,710**	**29,036**

Indirect Cost Amount	*15%*	*0%*	*17.5%*	

FY 2007 costs.

	FY 2007 USGS IAA	FY 2007 NPS Funds	FY 2007 HPI-CESU Agreement	Total Funds
Personnel				-
Travel	14,070	3,686		17,756
Materials & Supplies				-
Equipment				-
Subtotal	14,070	3,686	-	17,756
Indirect Costs	2,111	-	-	2,111
TOTAL	**16,181**	**3,686**	-	**19,867**

Indirect Cost Amount	*15%*	*0%*	*17.5%*

The total request to the PACN I&M Program for this project is $ 114,379.

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LANDBIRDS

Prepared by: Rick Camp (last modified 08/04/05)

Protocol: Focal Terrestrial Vertebrate Species: Landbirds [short name: landbirds]

Parks Where Protocol May be Implemented: AMME, NPSA, KALA, HALE, HAVO

Justification/Issues being addressed: Birds are the principal, and sometimes only, terrestrial vertebrates on islands. Empowered by flight, birds typically out-distance mammals, reptiles, and amphibians in their ability to reach and colonize islands. This same long-distance filter also hinders the competitors, diseases, and predators of birds from reaching islands. Largely free from the factors that limit bird populations on continents, the Pacific islands originally were havens for birds. Two characteristics of island bird communities are (a) population densities were, and often still are, much higher than on continents, and (b) island birds have lost some defenses to biotic factors that would exploit them. Furthermore, from their position at the top of the terrestrial food chain, birds more strongly influence ecological processes on islands than on continents as consumers, pollinators, and seed vectors. On Pacific islands, birds pollinate the majority of woody plant species and disperse their seeds. Lastly, bird populations marooned on islands inevitably change, and with enough time evolve into new species. As a consequence, the avifaunas of Pacific islands are composed overwhelmingly of endemic species.

Since humans have settled Pacific islands and have introduced a long and growing roster of introduced species, the biota of islands are becoming more continental in composition and ecology, almost invariably to the detriment of native birds. The most drastic and infamous impacts, for example non-native rats and avian diseases, have brought about extinction of a large proportion of the original avifauna, and many of the surviving species are greatly reduced. However, hope remains for Pacific island birds in situations where they can escape alien threats (e.g. high elevation rainforests), can be assisted by human management of ecosystems, or can ultimately adapt to novel pressures.

The native forests in PACN harbor bird communities that not only are representative for each island, but in many cases are of greatest importance to the conservation of the birds themselves. Significant examples include the bird communities at Kipahulu in HALE, Kahuku in HAVO, all four island units in NPSA, and to lesser extent the modified habitat at AMME. Focal terrestrial vertebrate species, for the most part birds, were ranked fourth as vital signs by the PACN network.

Specific Monitoring Questions and Objectives to be Addressed by the Protocol:

1. Determine long-term trends in species composition and abundance of native and non-native forest land bird species in PACN parks – AMME, NPSA, KALA, HALE, and HAVO.

   Objective 1a: Determine the distribution and density of all non-threatened native and most non-native land bird species. Conduct systematic surveys in suitable habitat using variable circular plot counts.

   Justification: Tracking population distribution and density provides fundamental information for monitoring patterns of population change. These data from species with relatively low extinction risk can be used to describe trends from vital sign taxa that are expected to readily respond to environmental changes. For example, while it is difficult to distinguish the component effects of limiting factors on native bird distribution and numbers, the observed pattern in Hawaii has been a retreat to cooler elevations, primarily in response to uphill spread of disease and disease vectors (mosquitoes), likely a consequence of global warming. The existing long-term datasets at HALE and HAVO gives these parks a head start toward meeting this objective and continued monitoring will strengthen the results.

Objective 1b: Determine the distribution and estimate reproductive success and annual survival for birds of special interest, including threatened and endangered species, species of concern, and species that require more precise monitoring than is provided by count surveys.
Justification: Distribution and demographic parameters, such as reproductive success and annual survival, provides critical information for understanding patterns of population change as deterministic processes are typically more sensitive and better reflect population changes (Steidl 2001). Population trends can be better understood from monitoring the interaction of these demographic parameters (e.g., BBIRD and MAPS).

Objective 1c: Document all observations of rare or elusive birds, or newly arrived invasive bird species. Observations of these birds will be recorded using Wildlife Observation forms (standardized forms documenting information on species, time, date, location, and observer). Furthermore, population size and extinction risk can be assessed for rare and elusive birds using area-search methods.
Justification: Two objectives are involved: monitoring rare native species versus incipient invasion of either native or non-native birds. These species are at either end of their population histories, one on the verge of extinction, the other at the forefront of invasion. Rare birds are difficult to monitor, and every effort should be made to recover incidental data that can be meaningful to the history of their populations in the parks.

2. Monitor land bird population and community changes relative to management activities in PACN parks – AMME, NPSA, KALA, HALE, and HAVO.

Objective 2: Monitor the changes in population abundance and species composition of native and non-native forest passerine species relative to management actions corresponding to forest restoration (i.e., alien plant and animal control) and reforestation. \
Justification: The restoration and recovery of ecosystems in the parks could have a strong positive effect on native bird species. Understanding and predicting how management actions relate to bird abundance and species composition is useful for evaluating management activities and identifying further conservation actions. Monitoring for this objective will be co-located with vegetation monitoring, although co-visitation may not be coincident.

Basic Approach:
Standard approaches to monitoring land birds have been refined for Pacific islands (Camp et al in review). For species detected frequently, variable circular plot counts can generate density estimates and proportion of area occupied, whereas rare bird searches offer another quantitative approach to monitoring populations of seldom encountered species. Species with high intra-

annual variability and species of special interest may require tracking population changes using mist-netting and banding (e.g., MAPS), and nest searching (e.g., BBIRD).

Variable Circular Plot: To meet objectives 1a and 2 for non-threatened birds, surveys using VCP methods will be conducted to monitor species densities. VCP counts have been used for decades in Pacific islands to census forest birds, and the technique is recognized as a reliable method to estimate bird density and population size (Rosenstock et al. 2002). VCP is a point-count methodology that incorporates detection probability into population estimates. The study area is sampled at stations distributed along transects. The distances from the station center point to all birds seen or heard are recorded during an 8-minute sampling period, along with the sampling conditions. Data will be analyzed with program Distance, accounting for covariates, and post-stratified when necessary (Thomas et al. 2002). The Hawaii Forest Bird Interagency Database Program of the U.S.G.S. Pacific Island Ecosystems Research Center has acquired all past data for Hawaii, including the national parks. Under contract from NPS, the HFBIDP is currently analyzing these data. This program could also assist with future management and analysis of PACN bird data.

Proportion Area Occupied: To meet objective 1a for non-threatened birds, PAO will be conducted to monitor species distributions. PAO is an analytical methodology applied to point count data that incorporates detection probabilities to estimate the area occupied by a species. Occurrence data (presence and absence) will be derived from VCP sampling stations for the total area and from repeated surveys of a subset of stations to estimate the probability of detecting the species (MacKenzie et al. 2002, 2003). The repeated surveys will be conducted within a relatively short time period to ensure closure and from sites that are representative of the study area. Data will be analyzed with program Presence (MacKenzie http://www.proteus.co.nz).

Rare bird searches: To meet objective 1c for rare or elusive birds, area-search methods will be conducted to monitor both distribution and density. This monitoring approach will be used for select species. Based on area-search methods (Ralph et al. 1993), RBS have been used for locating extremely rare and elusive birds in Hawaii (Reynolds & Snetsinger 2001) and as a nation-wide bird monitoring program in Australia (Ambrose 1989). Two-person survey teams continuously observe during timed searches in a given area or along transects. Observers move through the area in a systematic manner and continuously record and map the all individuals observed (by species, and sex and age when possible). Data will be analyzed following methods detailed in Reynolds & Snetsinger (2001). Additionally for territorial species, spot-mapping can document species occurrence and produce population estimates, which when repeated over a period of years can yield trends (Ralph et al. 1993).

Mark-resighting methods: To meet objective 1b for threatened and endangered species and birds of special interest, intensive sampling methods, such as mark-resighting techniques, will be conducted to monitor demographic parameters. This monitoring approach will be used for select species. Mist-netting and banding forest birds is the standard method for estimating post-fledgling survival rates and a standard survey protocol has been applied to a nation-wide monitoring program (MAPS; DeSante et al. 2001). Birds are sampled using a constant-effort mist-netting protocol at ten net-sites for six to ten consecutive 10-day periods during the breeding period. In addition, all birds detected or captured at each station are assigned a breeding status, and these data are used to assign a composite breeding status for every species (detailed sampling methods are outlined in DeSante et al. 2001). Data will be analyzed with program MARK (White & Burnham 1999).

Nest searching and monitoring: To meet objective 1b for threatened and endangered species and birds of special interest, intensive sampling methods, such as nest searching techniques, will be conducted to monitor demographic parameters. This monitoring approach will be used for select species. Estimating reproductive success, a demographic parameter that is needed to understand population change, relies on nest searching and monitoring following the nation-wide monitoring program BBIRD (Martin et al. 1997). Breeding productivity is determined at randomly-located replicate plots by searching for nests and monitoring them through fledging (detailed sampling methods are outlined in Martin et al. 1997). Data will be analyzed following standard BBIRD protocol.

Habitat monitoring: To meet all of the objectives, specifically objective 2, habitat monitoring will be conducted. Bird distribution and numbers are likely to change with potential habitat changes over time. Therefore, it is necessary to periodically (interval of decade) characterize land cover types from remotely sensed data, and determine forest habitat structure (interval of five years; e.g., open, closed, woodland, etc.), and spatial extent. Vegetation sampling and analysis will follow standard NPS protocol. Additionally, correlating land-cover type and structure (coordination with focal terrestrial plant species, focal terrestrial plant communities, and land use patterns vital signs) will aid in monitoring bird distributions and abundances.

Coordination with Other Vital Signs: Coordination and co-location with focal terrestrial plant species, focal terrestrial plant communities, exotic terrestrial plants – early detection, invasive/exotic animals, and land use patterns vital signs will be necessary to address habitat correlation with changes in land birds. While much of this is addressed in a coordinated spatial sampling design, communication regarding other aspects of this vital sign is required.

Overall approach: Protocols for the above surveying methodologies already exist. Therefore, protocol development will not require field research and instead will consist primarily of designing sampling schemes tailored to each park and its avifauna. Park-specific protocols are required, because Pacific parks encompass completely different avifaunas inhabiting a wide variety of habitat types, from forest, to scrub, mangroves, and grassland. Protocols will meet NPS standards (Oakley et al. 2003), incorporate existing sampling, and propose new sampling in order to achieve the most efficient and informative monitoring. Therefore, particular attention will be given to determining sample size and allocation, sampling frequency, and ability to detect trends. The protocol narratives and SOPs will describe each sampling scheme and document how data will be entered into NPS computers, analyzed, and reported need to be written.

AMME and NPSA: (1) Establish point count surveys in land bird habitat; (2) Establish mist-netting and nest searching within the Nightingale Reed-Warbler (*Acrocephalus luscinia*) distribution in AMME operated during the breeding season only; and (3) Conduct vegetation sampling at all survey sites once every five years.

KALA, HALE and HAVO: (1) Continue point count surveys at previously established stations and fill in a grid-work of transects and stations that best represent the bird populations and measure their trends; (2) Establish point count surveys in KALA in montane forests; (3) Establish demographic monitoring, via bird-banding and nest-monitoring, for the Akiapolaau (*Hemignathus munroi*), Hawaii Creeper (*Oreomystis mana*), and Hawaii Akepa (*Loxops coccineus*) populations within the Kahuku section of HAVO; and (4) Conduct vegetation sampling at all survey sites once every five years.

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Development Schedule, Budget, and Expected Interim Products: The work is expected to take about nine months. The product would be a plan for monitoring forest birds in the PACN.

Table1. *FY2006 costs.*

Category	**Details**	**FY2006 HPI-CESU Agreement**
Personnel	1 GS 9, 0.5 FTE and 1 GS 9, 0.1 FTE	$42,000
Travel	1 x Hawaii-NPSA; 1 x Hawaii-AMME	$8,000
Materials & Supplies	office and field supplies	$0
Meetings	2 x Technical Committee meeting for protocol development	$500
TOTAL		$50,500

Benchmarks:

Fiscal Year 2005

June 01 2005

- Prepare interagency agreement based on draft of study plan

Fiscal Year 2006

January 02 2006

- Initiate study plan development

March 31 2006

- Draft sampling design (delineate sampling areas, determine necessary sample sizes, determine accessibility, select sampling sites, prepare Minimum Tool Analysis for applicable park units).
- Draft design specifications for monitoring database provided to PACN data manager

May 31 2006

- Draft text of protocol narrative and common SOPs such as GPS use, field safety, training requirements, etc.
- Conduct aerial and on-ground reconnaissance to refine ecological subsections and selected plot boundaries in west Pacific parks (i.e., AMME and NPSA).

October 31 2006

- Draft protocol study plan submitted to peer review
- Draft SOPs completed for all identified needs

Fiscal Year 2007

January 31 2007

- Return of peer reviewed draft protocol study plan

March 31 2007

- Submit revised final protocol study plan

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SEABIRDS

Prepared by: Darcy Hu

Protocol: Focal terrestrial vertebrate species: Seabirds

Parks Where Protocol May be Implemented: NPSA, KALA, HALE, KAHO, HAVO, possibly AMME, WAPA. Initial suggested implementation: HAVO, NPSA, HALE, KAHO, KALA

Justification/Issues being addressed: Birds currently form a significant component of the native terrestrial vertebrate fauna for islands in the network. Prior to human colonization, seabirds nested widely and in enormous numbers on all network islands. However, today the group is marked by precipitous declines and extirpations on all inhabited islands. Any extant colonies are remnants in dire need of protection, active monitoring, and management.

Seabirds served as food sources for Hawaiians and Samoans (USFWS 2005). In ancient times, the 'Ua'u were considered a delicacy, reserved for the Hawaiian royalty, or *'ali'i*. There is direct archeological evidence of their use as food in HAVO (J. Nakamura pers. comm.). Seabirds played additional roles in native Hawaiian culture: both modern and historic Hawaiian culture utilized seabirds to navigate to fishing locations and land while on the ocean, and some modern Hawaiian families identify themselves with particular seabird species through chants and dances.

Ecologically, seabirds undoubtedly played a significant role in cycling nutrients, as huge numbers of birds brought marine food to land to feed chicks. Presently, seabirds serve as indicators of the condition of their marine food sources (e.g., Montevecchi 2002), marine habitat condition, nesting and roosting habitat integrity, invasive species impacts, and the effects of human population expansion and associated habitat loss (O'Connor & Rauzon 2004).

Rare, threatened and endangered seabird species are of primary concern to PACN. Two species are federally listed as threatened or endangered: the Hawaiian Petrel (HAPE, *Pterodroma sandwichensis*, 'Ua'u) is listed as endangered, and the Newell's Shearwater (NESH, *Puffinis newelli*, 'A'o) is threatened. Both species are either known to or thought to occur at HALE, HAVO and KALA. Other rare species include Band-rumped Storm-petrel (BRSP, *Oceanodroma castro*, 'Ake'ake) that occurs at HAVO and possibly HALE and KALA. Tahiti Petrel (TAPE, *Pterodroma rostrata*), Herald's Petrel (HEPE, *Pterodroma arminjoniana*), and Polynesian Storm-petrel (POSP, *Nesofregetta fuliginosa*) may still occur at NPSA.

The Regional Seabird Conservation Plan, Pacific Region (USFWS 2005) encourages coordinated seabird inventory, monitoring, and reporting, as well as further work to identify factors limiting declining populations. As a first step, the USGS is evaluating existing USFWS seabird monitoring data from the Pacific Islands (M. Naughton and M. Reynolds, pers. comm. 2005). The USGS will then make monitoring recommendations, including methods revision, sampling design, and sample size, distribution and intensity, to increase the ability of monitoring to detect trends.

Detection of trends in seabird populations or in reproductive success may prove difficult, both due to the amount of annual variation observed in these long-lived birds, and because of infrequent monitoring due to difficulties or expense of sampling. Because it is critical for our monitoring to be able to detect biologically meaningful population changes in a reasonable amount of time, this USGS evaluation affords the NPS the opportunity to use or adapt some of the resulting sampling recommendations and thresholds for trend detection for use in park units. Use of USGS recommendations also can allow NPS to link its seabird monitoring with other work being conducted in the US Pacific Islands. Because the USFWS data evaluation has not been completed, our methods, and even monitoring questions or objectives, may change to reflect these recommendations. We will also build upon this data evaluation by working with a statistician or quantitative ecologist to conduct similar work directed at species unique to PACN parks.

Additionally, there is concern about human disturbance when monitoring seabird species. NESH on Kaua'i and Hawai`i nest in dense vegetation that supports burrows and may protect the birds from predators such as pigs and cats. Depredated NESH were discovered at burrows where trails were made to monitor nests (Tom Telfer, pers. com.). Investigators collapsed WTSH burrows when monitoring densely populated nests on Molokini, offshore of Maui (Cathleen Bailey, pers. com.). In such species, remote monitoring of populations may be necessary.

Monitoring Objectives

Seabird monitoring in PACN has a single general objective of monitoring long-term population trends in three groups of seabirds:

1) Endangered Species: HAPE
   a. Trends in colony distribution and density over large geographic scales
   b. Trends in recruitment and reproductive success (in plots)
   c. Comparison of these same parameters in locations with and without predator control, or in same location before and after control.

2) Species of special interest (other threatened and rare species): NESH, HEPE, TAPE, BRSP, POSP
   a. Determine presence and detect trends in relative abundance (via a technique such as radar)
   b. If logistically possible, determine trends in reproductive success (sampling in plots)
   c. Comparison of above parameters in locations with and without predator control or other management actions, or in same location before and after management.

3) "Common" low-elevation species: RFBO, BRBO, WTSH, WTTB
   a. Trends in abundance and distribution
   b. Where colonies are visible or accessible and not highly vulnerable to researcher disturbance, assess colony density
   c. Comparison of these parameters in locations with and without management (e.g., predator control, reduction of human disturbance), or in same location before and after management.

Specific Monitoring Questions and Objectives to be addressed by the Protocol:

Question 1: What are long-term trends in colony distribution, colony size, recruitment and reproduction of HAPEs at HALE and HAVO, and are these affected by predator control?

Objective 1a: Detect changes in distribution of petrel colonies by searching suitable nesting habitat at intervals of every 5-10 years. For colonies found, calculate density by locating active nests or searching sample plots and then delineating colony area.

Objective 1b: Determine numbers of active nests and annual fledging success of HAPE at HAVO and HALE.

Objective 1c: Where predator control is or will be undertaken by the park, monitoring can be initiated to compare numbers of active nests and fledging success with areas in which there is no management, or with data collected before management was initiated.

Justification*:* HAPE is the only federally endangered seabird breeding in the Pacific Islands (50 CFR 17, 1999). HALE and HAVO contain the only colonies within actively managed reserve areas in Hawaii. Current threats to the HAPE at HALE and HAVO include habitat loss as a result of feral ungulates and predation by introduced mammals (Simons 1983, Hodges 1994, Hodges and Nagata 2001, Hu et al. 2001). Baseline information is extensive at HALE because of the relative ease in accessing the population. This information shows that the population at HALE is relatively healthy with over 1400 known burrows and slowly increasing (HALE unpubl. data). Baseline information is minimal at HAVO because colonies are logistically difficult to access. Current information suggests the population is in danger, with less than 60 known, active burrows, all at risk from feral cat depredation. Without monitoring and management, this HAVO population may be extirpated. Monitoring of HAPE via the NPS I&M program will focus primarily on HAVO populations, but will be designed and conducted to allow comparisons with HALE monitoring data.

Question 2: Determine presence, activities (i.e., whether and when species are breeding) and trends in populations and/or reproductive success of species of interest in PACN parks.

Objective 2a: Determine whether species are present by non-intrusive means such as radar and combined use of night vision and call recognition. Use this same technique to assess changes in relative abundance.

Objective 2b: Periodically (<annually) monitor reproductive success in plots.

Objective 2c: Where management is or will be undertaken by the park, monitoring can be initiated to compare numbers of active nests and fledging success with areas in which there is no management, or with data collected before management was initiated.

Justification: NESH are federally listed as Threatened (50 CFR 17, 1999). Although not federally listed, BRSP, HEPE, TAPE, and POSP are rare and of concern for PACN parks. All species are thought to occur in PACN, but little information is known. Because many seabird species have low reproductive rates, deferred sexual maturity, high adult survival rates, and range over large expanses of ocean, significant changes in their populations would be expected to incorporate large-scale environmental effects (Croxall and Rothery 1991), and chronic local deleterious impacts such as predation at colonies. These changes can act as signals of both insidious and acute impacts (O'Connor & Rauzon 2004). However, population estimates of burrow nesters while in their colonies are typically very difficult to make, particularly in the habitat in PACN parks. Such estimates would likely have very large confidence intervals, be expensive to undertake, and data collection could be destructive to burrows. Alternatively, declines in reproductive success inform us of colony-based or at-sea problems during the breeding cycle that result in loss of adults, eggs or chicks, including the known threats to network procellarid colonies from alien predators. Declines in recruitment may not manifest themselves as population declines for several-to-many years due to delayed age at first reproduction.

Question 3: Determine long-term trends in the number, distribution, and size of colonies of common, low-elevation seabirds at HALE, HAVO, KALA, KAHO, PUHO, NPSA, AMME and WAPA. Seabird species include: wedge-tailed shearwaters (WTSH), white-tailed tropicbirds (WTTR), red-footed boobies (RFBO), brown boobies (BRBO), black noddies (BLNO) and white terns (WHTE).

Objective 3a: Use repeated surveys along prescribed routes, or counts from fixed points, to assess changes in distribution and relative abundance of common seabirds.

Objective3b: If accessible colonies exist where human disturbance will not disrupt nesting, determine changes in colony density over time. This may involve establishing plots for larger colonies.

Objective 3c: Where predator control or reductions in human disturbance is or will be undertaken by the park, monitoring can be initiated to compare numbers of active nests and fledging success with areas in which there is no management, or with data collected before management was initiated.

Justification: Coastal habitat occurs across the network, and its vegetative restoration is a focus in many parks. Seabirds are a faunal component of the community that can also be encouraged and restored. Wedge-tailed shearwaters have begun to recolonize coastal sites on Oahu in the Hawaiian Islands. We anticipate that this species may attempt to recolonize network parks, as well. An initial colonization attempt at KAHO several years ago apparently ended when burrows were destroyed during high seas. The presence of this fairly robust species could signal that predator pressure and/or human disturbance have been reduced. Detection of new colonies would allow parks to institute management to protect and further encourage colonizers.

Additional species use coastal habitat in many PACN parks, including offshore islets that can serve as refugia from predators and human disturbance. Seabirds on KALA offshore islets, as well as those on an islet adjacent to AMME, could be included in this monitoring.

In addition to WTSHs, NPSA has over two dozen species of seabirds reported (O'Connor and Rauzon 2004), the highest seabird diversity of any PACN park. Approximately five species use coastal habitat in the park, while another four or more species use low and mid-elevation habitat. An initial inventory confirms that park lands are disproportionately used by several species, presumably because of reduced human disturbance within the park. Trends in these species are also important to monitor.

Justification: Management activity occurs within all PACN parks. Actions to restore ecosystems tend to result in positive effects on native species. Management activity conducted for administrative purposes and to enhance visitor enjoyment (road, building or trail improvements, etc.) can conflict with populations of seabird species.

Basic Approach:
The species and groups selected here nest in higher elevation montane or subalpine habitat (Objectives 1) and coastal and lowland or mid-elevation areas (Objective 2). Protocols to monitor HAPE have been developed at HALE and adapted by HAVO. These protocols will be used as a basis to develop protocols for comparative monitoring of HAPE at both parks. Remote monitoring of other species of interest may be necessary because of concern for habitat disturbance and logistic difficulties in finding and reaching colonies. Remote monitoring may include at-sea surveys, boat and/or shoreline surveys of coastal species, counts of birds leaving or returning to islands from key vantage points, acoustic monitoring, or radar surveys.

Initial intensive inventories for species of interest at NPSA are needed to gather basic information on presence/absence, seasonality, and gross distribution. Following that, remote monitoring may be necessary because of concern for habitat disturbance and logistic difficulties in finding and reaching colonies.

Monitoring of coastal strand species can be accomplished on foot for smaller parks, with a combination of searchers during daylight and aural searches at night augmented by night vision equipment.

O'Connor and Rauzon (2004) recommend a variety of monitoring for NPSA. Methods include at-sea counts in a small boat around the park and island shorelines, as well as "fixed location counts" at specified locations within the park (including some colonies), primarily in the Tutuila unit. Both of these approaches will yield relative abundance and species diversity information (O'Connor and Rauzon 2004).

Monitoring of HAPE and species of concern may occur annually, while monitoring of some common species (e.g., species in some of the NPSA park units) may occur in longer intervals, perhaps every 4-5 years. Lower elevation-nesting species have been monitored for decades in the NWHI and some islets off-shore of the main Hawaiian Islands; they are presently monitored by several different agencies. It is highly desirable to coordinate some of the protocols proposed here in order to look at larger scale changes in this group. However, evaluation of these existing methods is underway. Building NPS protocols on the evaluation now underway will enable us to standardize our data collection and compare results with partners.

Both HAPEs and WTSHs have similar foraging strategies, feeding in association with tuna schools (USFWS 2005). Thus, monitoring these two species concurrently may allow us to better understand or identify changes at the breeding colonies that result from changes at sea.

Contact with relevant agencies (USFWS Remote Islands Refuges and Portland regional office, DOFAW in Hawaii, DMWR in American Samoa) has been initiated.

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Development Schedule and Interim Products:
The schedule presented below reflects the estimated duration of tasks required for protocol development. We suggest developing protocols in phases. Since protocols for monitoring HAPE are already developed, phase I involves the complete development of HAPE monitoring protocols for HAVO in FY06. Phase II involves investigating and developing monitoring methods for species of special interest. Investigations will occur in FY06 and complete protocol development will be in FY07. Phase III involves investigating and developing monitoring methods for coastal species. Investigations will occur in FY06 and complete protocol development will be in FY08.

Budget:

FY05 Funds

	Description	**FY2005 NPS Funds**	**FY 2005 HPI CESU Agreement**	**Total Funds**
Personnel	CESU facilitator monthly cost ($3904) includes 30% benefits, assume 7% pay increase in July 2006; 1/2 time Jul 2006-Aug 2007 (14 months)		$28,000	$28,000
Travel	to KALA for on-site scoping (CESU cooperator Ackerman in FY07)		$ 600	$ 600
	to KALA for on-site scoping (co-PI Duffy)		$ 600	$ 600
	to HAVO for Stats consultation (Oct 2006, Duffy)		$ 300	$ 300
	To W Hawaii for on-site scoping (Ackerman in FY07)		$ 100	$ 100
	To W Hawaii for on-site scoping (Duffy in FY07)		$ 400	$ 400
	One additional protocol meeting in FY07 per instructions below (under Meetings) for Duffy and Ackerman		$ 600	$ 600

Materials & Supplies				
Equipment				
Subtotal			$30,600	$30,600
Indirect Costs	17.5% CESU rate			$ 5,355
Total				$35,955

FY06 Funds

	Description	FY 2006 NPS Funds	FY 2006 HPI CESU Agreement	Total Funds
Personnel				
Travel	to NPSA for on-site scoping (Hu's actual cost)	$3,081		$ 3,081
Materials & Supplies	Misc. for NPSA trip (batteries, Fed Ex, etc.), estimated	$ 100		$ 100
Subtotal		$ 3,181		$ 3,181
Indirect Costs				
Total				$ 3,181

FY07 Funds

	Description	FY 2007 NPS Funds	FY 2007 HPI CESU Agreement	Total Funds
Personnel				
Travel	to KALA for on-site scoping (Hu, Bailey)	$ 1,200		$ 1,200
	to HAVO for Stats consultation (Oct 2006, Bailey)	$ 300		$ 300

	To W Hawaii for on-site scoping (Hu)	$ 200		$ 200
	One additional meeting per instructions below (see Meetings), Hu and Bailey	$ 600		$ 600
	Reconnaissance of HAVO HAPE colonies	$ 800		$ 800
Materials & Supplies	Misc. supplies for KALA scoping (estimated)	$ 100		$ 100
Subtotal		$ 3,200		$ 3,200
Indirect Costs				
Total				$ 3,200

Budget Summary by Category (2005-2007):	
Personnel	$28,000
Supplies	$200
Travel:	$8,781
Indirect	$5,355
TOTAL	**$42,336**

The total request to the PACN I&M Program for this project is $ 42,336.

This protocol development budget includes an estimate for work with a statistician that the network will hire, contract, or cooperate with to develop network-wide Vital Signs sampling plans. This individual will assist in developing sampling plans and analysis techniques for these protocols.

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INSECTIVOROUS BATS

Prepared by: Heather Fraser (last modified 09/12/2006)

Protocol: Insectivorous Bats in the Hawaiian Islands

Parks where Protocol May be Implemented: HAVO, PUHE, PUHO, KAHO, HALE, KALA, and ALKA

Justification/ Issues being addressed:
Insectivorous bats are known to be of economic importance as predators of pest insects. However, they also contribute largely to mammalian biodiversity, especially on geographically isolated islands. In many island systems, bats are often the only native terrestrial mammals. The Hawaiian hoary bat (*Lasiurus cinereus semotus*) is an endemic subspecies and is the only extant bat established in the Hawaiian Islands (Stone and Pratt 2002). The Hawaiian hoary bat was listed as an endangered species in 1970 by the U.S. Fish and Wildlife Service (U.S. Fish and Wildlife Service 1970); however, current information regarding natural history and population status of this bat is scarce, resulting in incomplete and sometimes conflicting reports. Population estimates for the Hawaiian hoary bat range from hundreds (Altonn 1960) to thousands of individuals (Tomich 1974), but these numbers are based on anecdotal and incomplete data. Due to a lack of knowledge concerning status, potential distribution, relative abundance, and habitat needs, coupled with conflicting and vague reports of population estimates, long-term monitoring is critical to the survival of this species.

Specific Monitoring Questions and Objectives to be Addressed by the Protocol:

Questions:

- *What is the distribution of the hoary bat in national parks of Hawaii? What are the long-term (8-10 years) changes in seasonal occurrence of these bats in native, exotic, and mixed (native and exotic) vegetation types at high and low elevation sites, as well as open ocean sites?*
- *In what general habitat types are Hawaiian hoary bats observed?*

Objectives:

Objective 1: Determine presence, distribution, and relative activity levels of hoary bats in national parks of the Hawaiian Islands.

Justification: Although the Hawaiian hoary bat was listed as an endangered species in 1970 by the U.S. Fish and Wildlife Service (U.S. Fish and Wildlife Service 1970), much of this subspecies' natural history continues to be poorly understood. Sightings of the Hawaiian hoary bat have occurred from sea level to as high as 4,115 m (13,500 ft) at the summit crater of Mauna Loa Volcano (Tomich 1974). They have been observed flying and/or resting in a wide variety of both native and non-native vegetation types and landscapes (Tomich 1986b, Reynolds et al. 1998, Kepler and Scott 1990, Jacobs 1994, Menard 2001). Menard (2001) suggests that abundance and distribution patterns may fluctuate according to season and altitude on the Big Island of Hawai`i. Based on observations and audio detections of flying bats, she notes that a portion of the bat population seems to move upslope (sites ranging from 1,570 m to 1,890 m, mean July minimum temperatures 8-10°C) into the eastern highlands of the Hakalau Forest National Wildlife Refuge (NWR) and possibly sites within the Pōhakuloa Training Area, during the "post-lactation" period from September to December. She also observed Hawaiian hoary bats to be more common in the Hakalau Forest NWR between the months of January and March, during the "pre-pregnancy" period, rather than during the breeding season (April to August) when bats seem to shift in the lowlands of the island (sites ranging from 0 to 1,280 m, mean July minimum temperatures 11-20°C). Tomich (1986a), on the other hand, observed bats to be more common in upslope areas of Hawai`i in the May-August hot season and less abundant in coastal areas during that same time period. Similar results were found in studies of the Galapagos Islands subspecies (*Lasiurus cinereus villosissimus).* There, McCracken et al. (1997) also found hoary bats to be less active in lowland areas during the hot season.

Currently, acoustic bat detectors are being used to survey high and low elevation sites in the national parks of Hawaii to determine presence/absence of hoary bats. Based on findings from the Hawaiian hoary bat inventory and ongoing surveys, suggestions will be made for selection of representative monitoring sites in the Hawaiian Island national parks. In addition, development of this monitoring protocol will incorporate changes in seasonal distribution and activity among open ocean sites and high and low elevations in native, exotic, and mixed vegetation types believed to provide foraging opportunities for Hawaiian hoary bats. This can help to improve our understanding of relationships between these insectivorous bats and their habitats, as well as relative activity patterns. Activity patterns may then serve as an index for relative abundance, allowing for inferences to be made regarding changes in bat occurrence over time or between study areas.

Objective 2: Determine foraging habitats associated with hoary bats in national parks of the Hawaiian Islands.

Justification: Habitat use is largely unknown or poorly documented for Hawaiian hoary bats. By observing bat activity in various habitat types and identifying call types (e.g., search/contact calls v. feeding buzzes), researchers may make general inferences relating to habitat use. This will help park scientists to more effectively make decisions regarding management of critical foraging habitat.

Basic Approach:

Methodologies concerning monitoring of insectivorous bats can be found in the literature; however, review and field testing of these practices will be necessary to develop a successful long-term monitoring program. Information pertaining to population trends of solitary foliage roosting bats is anecdotal, making comparisons of past monitoring data complicated, if not impossible (Carter et al. 2003). Current methods and data constraints do not allow for quantitative comparisons to be made, so researchers are left to infer trends based on potential habitat availability or changes in bat activity over time. Therefore, it is necessary to establish standardized survey methods and implement these in all field locations. It is imperative that field survey crews observe and track bats in the same manner. Through systematic sampling and field survey methods, results of successive surveys can more realistically be compared, as observer and environmental variability can produce inaccurate results. Protocol development for the above objectives will most effectively be carried out in a series of phases.

Phase 1
An initial investigation of possible locations of Hawaiian hoary bats in sample areas should be done through literature reviews and interviews with local residents and park personnel, as well as other scientists working with insectivorous bats. This has already occurred in the Hawaiian Islands through an inventory of hoary bats in HAVO, PUHE, PUHO, KAHO, HALE, and KALA. Similarly, additional surveys for Hawaiian hoary bats along ALKA will be conducted before protocol development begins in these areas. Maps describing vegetation, landscapes, sites of cultural importance, and other significant features should also be developed to help in selection of study areas.

Phase 2
Both visual and acoustic detection are commonly used methods for bat studies, but development of long-term monitoring techniques for this protocol will focus on using acoustic detection equipment. Acoustic bat detectors provide a suitable and affordable alternative for bat monitoring studies, as volunteers can be utilized and a minimal amount of training is required (Walsh et al. 2003). Ultrasonic detectors can provide information on: (1) the presence or absence of echolocating bats and (2) the presence or absence of feeding activity (Thomas and West 1989).

Techniques for monitoring echolocating bats might include detections of bats along randomly placed transect lines, point surveys (Reynolds et al. 1998; Walsh et al. 2003), or automated monitoring stations. Anabat detectors will most likely be used, but other acoustic monitoring systems will be considered as they become available. Data will be recorded as bat activity per unit time. Because it is not possible to differentiate between several passes by one bat or single passes by several bats (Fenton 1970, British Columbia Resources Inventory Committee 1998, Johnston 2002), direct population density estimates are not possible (Thomas and West 1989, British Columbia Resources Inventory Committee 1998, Johnston 2002). However, relative measures of bat activity over time allow for monitoring of species trends based on detection of bat passes (U.S. Fish and Wildlife Service 1998). Bat activity may function as an index of bat numbers; for example, if activity per unit time decreases, then it is estimated that the number of bats has also decreased (Walsh et al. 2003).

Acoustic detection is also a helpful tool in determining various behaviors, according to call types emitted from bats (e.g., feeding buzzes vs. search/contact calls). General habitat associations (i.e. foraging areas) may then be suggested, based on detections of feeding buzzes. However, researchers should exercise caution when making these assessments, since detection of a feeding buzz does not necessarily imply preference for, or health of, a particular habitat.

Collaboration will be essential to the success of this effort and will involve investigators pursuing similar objectives in other Networks, including the Upper Columbia Basin Network, and with non-NPS efforts currently underway in Hawaii. Additionally, collaborative efforts will help to establish an acoustic bat monitoring group that may provide status and trend information at a much greater spatial scale (i.e., island wide).

Phase 3
Data analysis and final report.

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Development Schedule and Expected Interim Products:
This monitoring protocol will require 29 months to develop.

Task	Expected Duration
Literature review, compilation of methods	7 months
Visit parks, survey ALKA, site evaluation, field test methods, SOPs	7 months
Write the draft protocol (develop sampling design and field methods)	8 months
Peer review	5 months
Revise draft protocol, produce final monitoring protocol	2 months

Budget:

Description	I&M Cost
Personnel	45,825
Equipment	2,149
Supplies	0
Travel	15,270
Subtotal	63,244
Overhead (17.5%)	11,067
Total	**$74,311**

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Frugivorous Bats

Prepared by: Gail Ackerman (last modified 06/03/06)

Protocol: Focal Terrestrial Vertebrate Species: Flying Foxes

Parks Where Protocol May Be Implemented: NPSA, WAPA

Justification/Issues being addressed:
Large fruit bats, or flying foxes, are endemic to oceanic islands in the South Pacific, and are found in or near National Parks within the PACN. On geographically isolated islands with low biodiversity, flying foxes are ecologically important in maintaining tropical forest ecosystems through pollination and seed dispersal (Fujita & Tuttle 1991). Bats are the only terrestrial mammals found on the islands of Guam and American Samoa, and hold a key position at the top of the food chain as likely ecological indicators of forest ecosystem health and environmental change. Their demise and ultimate extinction could lead to a significant decline in tropical forest regeneration and diversity (Cox et al. 1991). Flying foxes have been historically subjected to commercial hunting, habitat loss, climatic disturbances, and predation, leading to population declines and a need for enhanced protection of habitat, along with elimination of hunting. Long-term monitoring of the Mariana fruit bat (*Pteropus mariannus mariannus*) of Guam, and the Samoan fruit bat (*P. samoensis)* and white-naped fruit bat (*P. tonganus*) of American Samoa, is critical to documenting population changes and identifying environmental stressors that affect populations, along with habitat needs.

The Mariana fruit bat was listed as endangered under the U.S. Endangered Species Act in 1984, although it was reclassified to threatened status in 2005. This subspecies was once thought to be isolated from other populations throughout the CNMI (Commonwealth of the Northern Mariana Islands), but the best available scientific information now indicates that all populations comprise one subspecies, as there is evidence that the fruit bats fly between islands in the archipelago (USFWS 2005). The Samoan fruit bat was designated as a Category 2 candidate under the Endangered Species Act in 1994, as a species of concern (O'Shea & Bogan 2003). The white-naped fruit bat has not been listed, although after severe hurricanes and extensive hunting in the 1990's, population levels decreased dramatically (Utzurrum et al. 2003). To change this trend, local hunting and exportation bans have been instituted on American Samoa and Guam for all three species as a result of declining population levels.

Specific Monitoring Questions and Objectives to be addressed by the Protocol:

Monitoring Questions:

1. *What is the distribution and relative abundance of flying foxes in and near NPSA and WAPA?*

2. *What habitat types are flying foxes associated with at NPSA and WAPA, and how are populations changing over the long-term (10-20 years) in preferred habitat associations?*

Protocol monitoring objectives:

Objective 1: Determine long-term trends (10-20 years) in relative abundance and distribution of flying foxes.

Justification: Assessing population changes or trends through periodic surveys will identify patterns of activity that could be related to environmental changes, food abundance and availability, poaching, and habitat alterations. The monitoring of distribution and relative abundance are important considerations in evaluating the health of pteropodid populations and in determining beneficial land management regimes, including habitat protection, control of hunting and control of invasive plant species, as well as introduced predators. Although population abundance of the three fruit bat species have been assessed on Guam and American Samoa for the last 20-25 years, lack of consistency in survey methods has led to inaccurate population estimates (Utzurrum et al. 2003). In addition, little published information is available regarding fruit bats communities within NPSA and WAPA.

Objective 2: Determine roosting and foraging habitats associated with flying foxes in and near NPSA and WAPA.

Justification: Habitat utilization by flying foxes is often described in terms of food sources exploited, and plant composition of survey areas. However, these surveys typically monitor the activity patterns themselves rather than actual habitat utilization. By identifying preferred habitat used during roosting, foraging and other behavioral activities, and monitoring these areas over a long-term study, NPS scientists can more effectively determine what habitat protection efforts may be needed to maintain and improve these sites for flying foxes, which could assist in the species recovery.

Survey Sites

Surveys conducted as part of the monitoring protocol will be carried out in forested habitat and along cliff lines where flight, roosting and foraging activities of flying foxes can be observed. The emphasis of monitoring surveys will be to conduct censuses at known bat colonies and to search for solitary bats and additional colonies. The same sites will be sampled at regular intervals. Survey sites identified in the literature are as follows:

Guam—Several sites were surveyed 1-2 times each in the upper Talofofo river watershed, above the confluence of the Maagas and Mahlac rivers (Morton & Wiles 2002), an area administered by the U.S. Navy as the Ordinance Annex. This area is well protected from illegal hunting and deforestation. The islands' only known colony of *P. m. mariannus* has roosted at one site on Pati Point at Anderson Air Force Base for several years (DAWR 2000), although from 1981-1994 colonies utilized 11 sites on Pati Point and 10 sites located between Ritidian Point and the northern rim of Tarague basin (Wiles et al. 1995).

American Samoa—Many of the surveys of *P. samoensis* and *P. tonganus* have been conducted on the largest island, Tutuila, although resident populations of these bats are also found on Ofu, Olosega, and Ta'u. Coastal forests on cliffs above the ocean, where temporary and stable roost sites were located, were monitored by boat due to the inaccessible terrain (Bannack & Grant 2002, Brooke et al. 2000, Craig et al. 1994). Thirty eight roost sites were identified in upland forest in several valleys and ridges, from 1987-1997 (Brooke et al. 2000). Additionally, valleys with an unimpeded view of the surrounding forest were used as bat flyways, such as in the Amalau (within NPSA) and Nu'uuli valleys (Brooke 2001). *P. tonganus* has also been found to roost in the Ottoville Lowland Forest and Olovalu crater in the Tafuna Plain, outside NPSA boundaries (Trail 1993).

Basic Approach:

Species Characteristics

Survey methods used to determine population abundance of flying foxes depend on the species monitored, access to sites, and time of day. *Pteropus m. mariannus* has a nocturnal pattern of activity, although it can be active in the daytime, especially in the early morning and late afternoon. This species typically forms large colonies, although solitary roosting and solitary flying fruit bats can be observed. *P. tonganus* is primarily nocturnal, forages in secondary forests and plantations, and forms colonial daytime roosts. *P. samoensis* is typically solitary and diurnal, although it may also be nocturnally active, and is found in primary and heavy growth secondary forests, and does not roost in a colony. Although the latter species is found in far fewer numbers than *P. tonganus*, it is similar in size and morphology, making identification between the species difficult at a distance. Coloration, wing shape and flight patterns are used to identify the species at closer range.

Survey Methodology

Several count techniques, which are often used in combination, have been successful in assessing the distribution and abundance of flying foxes (Kunz 2003, Utzurrum et al. 2003). Therefore, these will be evaluated in this protocol, and include:

1) **Direct roost/colony counts**, which are measured by counting individuals at known roosting sites from observation stations no more than 100-300 m distance, with binoculars or spotting scopes. These counts are possible in situations where roost trees are partly or completely defoliated, or where colonies are relatively small, so that most or all of the bats can be readily counted. However, direct colony counts do not represent a complete census, and for this reason, a correction factor of 5-10% has been applied to the total count where direct counts may not account for every bat in the colony, as some may be hidden by vegetation or roost mates (Wiles 1987a);

2) **Evening exit/emergence counts**, which are used to estimate colony size when the colony departs from a roost in trees, especially when the roost is physically inaccessible by humans. This count method is often employed to estimate remote colony size when direct counts will not yield accurate results (Utzurrum et al. 2003). Observers are positioned to best view bats against the sky as they depart the colony. Monitoring usually occurs from just before dusk to dark, when the first bat exits the colony. Ideally, evening emergence counts should be made over several consecutive nights to establish intra-colony variation in the number of bats present (Kunz 2003). Night vision may assist in counting individuals, although the equipment has a limited range of use. Infrared thermal imaging is a more accurate method for censusing bats in ambient light and should be considered for censusing colonies that number in the hundreds or higher, as individual bats can be counted by detecting their heat signatures (Kunz 2003). Emergence patterns of bats from one night to the next can be highly variable, as some bats may remain in the roost until nightfall, or disperse without being seen by observers. Therefore, the bats that disperse from a colony represent only a portion, or subset, of the total colony size (Utzurrum et al. 2003). Some researchers have applied a correction factor to estimate colony size, but these were often determined arbitrarily (Utzurrum et al. 2003);

3) **Station/vista counts**, which provide information on the number of bats moving through and feeding in each count location, and are often used to assess the abundance of solitary or extra-colonial fruit bats. These counts typically involve up to three observers at the same station, with unimpeded views of the landscape. Each observer scans the landscape with binoculars or a spotting scope and counts bats during eight 10-minute sessions (8 samples per site per month), followed by 5-minute intervals to allow a rest period and to minimize the potential of double-counting individual bats (Utzurrum et al. 2003). To estimate the number of bats at each site, a mean for the eight counts is calculated. Day counts in American Samoa have been standardized to start at dawn and end two hours later (Craig et al 1994, Brooke 2001). Late afternoon counts also last two hours and extend until dark or until colonial bats disperse and intermingle with solitary bats. Count results are based on the total number of active bats per unit area per unit time (Utzurrum et al. 2003). Craig et al. (1994) derived index abundance from the numbers of bats counted per km 2 per 10 min, and converted these counts to density estimates for the study area. These estimates, however, assume that bat activity at a count station is representative of the total number of solitary bats in similar habitats across an island. Using indices to estimate population size has been criticized (Utzurrum et al. 2003).

Difficulties attendant with station counts is that if a colony is very large, the likelihood of double-counting the same bats increases. Some bats may not be active during a specific count period and may not be recorded. Additionally, count variations have been noted between observers on American Samoa due to the utilization of inexperienced observers counting at many sites. After conducting a series of randomized counts, it was determined that 10 replicated counts (visits) per site were required to stabilize mean estimates (Morrell and Craig 1995).

Surveys will not only provide population estimates but will also record the number of nursing young and juveniles counted during and after the breeding season. Comparisons of breeding success from previous studies and these surveys will be done to determine if young are surviving to adulthood, therefore increasing population size;

4) **Mist-netting and radio-tracking techniques** may be employed to monitor movement patterns in relation to Park and non-Park lands, activity patterns, and preferred habitat associations. We may also evaluate movements around foraging and roosting sites, and evaluate activity levels (active vs. inactive). Mist-nets, with a mesh size of four-inches, will be set up in flyways and feeding areas, and bats captured will be fitted with radio-collars (<3% total body mass; 7 g in weight, Holohil Systems, Ltd, Canada), and may be banded to aid in identification if bats are recaptured after collars drop off. Either a numbered and colored plastic ring placed on the forearm, or a colored bead necklace, may be used to band each bat. Data may be collected on sex, age, weight, ear and forearm length, and breeding status. Only adult bats weighing more than 200 g will be radio-collared, as juvenile or lighter weight bats may be more physically challenged, and have higher energy expenditure, due to the weight of the collar.

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Development Schedule, and Expected Interim Products:
This monitoring protocol will require 23 months to complete.

Task	Expected Duration
Background, literature review	5 months
Visit parks, field test proposed methods	6 months
Write the draft protocol (sampling design, field methods, SOPs, etc.)	6 months
Send off to peer review	3 months
Finalize protocol	3 months

Budget

Table 1. *FY2005 costs.*

	FY2005 NPS Funds	FY2005 NPS In-kind Funds	FY2005 HPI-CESU Agreement
Personnel			
Travel			
Materials & Supplies			
Equipment			
Subtotal			
Overhead (17.5%)			
TOTAL	0	0	**$34,622**

Table 2. *FY2006 cost—October 2005-September 2006.*

	FY2006 NPS Funds	FY2006 NPS In-kind Funds	FY2006 HPI-CESU Agreement
Personnel			
Wildlife Biologist (RCUH), GS-8, Step 1 equivalent, 12 months			$34,000
Biological Technician – 6 Months NPSA, stipend ($20/day = $2,600/6 mo) + travel ($1,400)			4,000
Travel			
(includes hotel/car/food)			
1 x Hawaii—NPSA			2,500
($1,200)			3,000

1 x Hawaii—Guam ($1,300) Meetings—I & M, North American Bat Symposium			3,000
Materials & Supplies Books, office supplies		$300	
Equipment Items purchased (e.g. GPS units) for Guam inventory will be used for NPSA monitoring development			
Subtotal Salaries Purchases		 300	 38,000 8,500
Overhead 17.5% on salary 17.5% on purchases through RCUH		 0	 6,650 1,488
TOTAL	0	$300	$54,638
GRAND TOTAL			**$54,938**

Table 3. *FY2007 costs—October 2006-September 2007.*

	FY2007 NPS Funds	FY2007 NPS In-kind Funds	FY2007 HPI-CESU Agreement
Personnel Wildlife Biologist, GS-8, Step 1 equivalent, 9 months	0	0	$25,500
Travel (includes hotel/car/food) 1 x Guam – NPSA ($2,100) Meetings—I & M, North American Bat Symposium			 3,500 3,000
Materials & Supplies		200	
Equipment 4 x Mist nets, 4" mesh 10 x Radio-collars 2 x Receivers /Antennas	 600 2,100 2,000		
Subtotal Salaries Purchases	 4,700	 200	 25,500 6,500
Overhead 17.5% on salary 17.5% on purchases			 4,463 1,138
TOTAL	$4,700	$200	$37,601
GRAND TOTAL			**$42,501**

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FISHERIES HARVEST

Prepared by: Peter Craig

Parks where protocol will be implemented: KAHO, KALA, NPSA, WAPA

Justification/issues being addressed:

In the Pacific islands national parks, a wide variety of coral reef fish, invertebrates and algae are harvested annually in either traditional, artisanal, recreational or subsistence fisheries, and it is even legal to sell fish caught in several parks. The potential impact of a seemingly small but persistent level of daily fishing activity can be surprisingly substantial. For example, on a small island in American Samoa (including part of NPSA), only three subsistence fishermen, on average, were seen at any given time along 15 km of shoreline (Craig et al. 2005). Yet when extrapolated to an annual period, this amounts to 22,536 fishing hours/yr (no fishing on Sundays). One way to visualize the potential impact of this annual effort is that it equates to one person fishing continuously day and night for 2.0 months along each kilometer of shoreline.

Fishing has well documented, significant impacts on reef ecosystem structure and function, and on the condition of fish populations (e.g., Dayton 1998, Friedlander and DeMartini 2002, Birkeland 2004) and the economies of local islands (Cesar 2000). Effects of fishing can include shifts in fish size, abundance, age structure, and species composition, with indirect effects such as habitat modification through physical damage (e.g., Russ 1991). Fishing is increasingly being recognized as the principal threat to Pacific coral reefs and other marine ecosystems worldwide (e.g., Dayton 1998, Birkeland 2004, Hutchings and Reynolds 2004). In this respect, it is highly probable that most of the Pacific Islands parks can be categorized as "impaired" to "seriously impaired". Fishing ranked 11th in implementation rank as a network Vital Sign. It should be noted that most fisheries harvest information needed for PACN parks is not currently being collected by any other state, territory or federal agency, thus highlighting the need for the parks to collect their own data.

While this protocol focuses on marine fisheries, the methodology selected would be generally applicable to fisheries in freshwater habitats as well.

Specific monitoring question and objective to be addressed by the protocol:

Question: What are annual trends in quantity, composition, and size of fish and invertebrates extracted from park waters?

Objective: To monitor this Vital Sign, the objectives will be to assess fishing effort by gear type, catch per unit effort, composition and size of species harvested annually. Due to the expense and time required to gather such data (often 1 year), the time frame for this Vital Sign will to conduct a detailed assessment at multi-year intervals (e.g., once every 5 years), supported by a subsampling of selected fishery components in the intervening years.

Basic approach:

Fisheries data are routinely conducted by fisheries agencies around the world (e.g. AFS 1990, Dalzell et al. 1996, Hart and Reynolds 2002, Munro 2003). The basic objective is to annually determine the total harvest weight by species. For small-scale and widely dispersed fisheries that occur in Pacific Islands parks, it is usually not feasible to directly measure the total catch (i.e., all the fishermen do not land their catch at one location such as a harbor), thus a sub-sampling effort is commonly used and expanded to provide the annual harvest estimate (e.g., AFS 1990, Friedlander and Parrish 1997). The methodology to do this involves two basic types of survey data: (1) fishermen interviews (creel surveys) to determine catch composition and catch-per-unit-effort, and (2) participation surveys to determine fishing effort (ie, number of fishermen by gear type and by location).

Documentation of fishery harvests is usually a rather complex and time-consuming task for several reasons:

(1) *Extended sampling effort (typically a 1-year period).* It is necessary to sample fish catches over an extended period because fishing effort is not equal during all hours of the day or night, during all days of the year, or at all locations. For example, fishing effort may be tidally related, fishing effort commonly increases on weekends/holidays, and some species are only available seasonally.

(2) *Varied fisheries* (e.g., Dalzell et al. 1996, Friedlander & Parrish 1997). The types of fisheries occurring in PACN parks cover a broad spectrum, from the familiar sportsman angler to subsistence divers and reeftop gleaners hand-picking clams and octopus. There are also culturally important harvests for opihi (limpets) in the Hawaiian parks, palolo polychaetes are harvested on one special night of the year in American Samoa, and mass recruitment or migration events of newly settled juvenile surgeonfish, goatfish or other fishes such as aholehole and akule are harvested in American Samoa and Hawaii.

(3) *High statistical variability*. A large sample size is needed because of the many different gear types used, and because of the typically high statistical variability in individual catches in space and time. Consequently, data collection is stratified (by gear type, time of day and month, and location) to allow data to be extrapolated to an annual harvest quantity.

(4) Cost. A supervisor, two full-time technicians, and in some circumstances, a boat may be needed for a full year of data collection.

Sample design to determine fishing effort (participation surveys). In general, the study area is the entire marine component of each park that is reasonably accessible by land (road/trail, with use of binoculars) and/or boat. Some parks may also want to include areas adjacent to the park in the study area. A stratified random sampling design will be used to determine fishing effort. In recreational or subsistence fisheries, four temporal strata in which fishing effort will likely differ are: daytime, nighttime, weekdays, weekends/holidays. Additional strata could include tidal stage, season, gear type, location, etc., depending on park-specific needs. During each participation survey, a “snapshot” of fishing effort is documented, during which time the number and location of fishermen (by gear type) are recorded during a standardized time interval that is needed to conduct one complete survey of the study area. The average fishing effort per strata (number of hours per gear type/number of surveys) is expanded to the total number of hours within the strata.

Sample design to determine catch (creel surveys). For most parks, an opportunistic, roving creel survey will be used to interview fishermen to determine the length of time they have been fishing (to determine their catch-per-unit-effort) and the species composition, number and weight (or length) of their catch. In some cases, data collectors can be located at constriction points such as a boat harbor. Each creel examined provides a catch-per-unit-effort by species and gear type that can be multiplied times the total effort per strata (see above) to calculate the total catch by species (or species group). The number of samples needed can be considerable (eg, 10 gear types used in the fishery x 30 interviews/gear type x 4 time strata = 1,200 interviews over a 1-year period or 100/mo).

Although the overall methodology to monitor the fisheries at PACN parks is similar, an important component of the protocol will be to tailor the sampling design to each park-specific fishery that needs to be monitored. Due to the relatively large investment of time required to document a fishery, some parks may choose to focus on selected species and/or document annual catches at intervals of several years. This work will be facilitated by existing knowledge of many of the fisheries now occurring in network parks; other fisheries will become better known as monitoring efforts begin and accordingly, park-specific sampling designs can be adaptively changed.

Primary Investigators and NPS Lead:

PIs: Jim Beets, Marine Ecologist, University of Hawaii at Hilo, 808-933-3493, beets@hawaii.edu

Alan Friedlander, Pacific Coral Reef Science Coordinator, NOAA/NOS/NCCOS/CCMA/Biogeography Team, 808-259-3156, afriedlander@oceanicinstitute.org

NPS Lead: Peter Craig, Marine Ecologist, 684-633-7082, Peter_Craig@nps.gov

WORK SCHEDULE: A preliminary timeline for the Fisheries Protocol (Phase 1) is shown, and benchmark dates are highlighted in Table 1.

Table 1. Draft timeline for developing the Fish Harvest Protocol (Phase 1). 15-Jul-06

	2005			2006												2007												2008											
Task	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
Protocol study plan																																							
site visits	x																																						
literature review		x	x	x																																			
draft study plan															x																								
finalize																x																							
Sampling design																																							
dataset analysis																		x																					
PI draft study design																				x																			
Chapt. 2 & related SOP																							x																
finalize																									x														
Database preparation																																							
draft database																									x														
finalize																												x											
Field testing																																							
NPSA																									x														
KALA																										x													
WAPA																												x											
KAHO																													x										
Protocol development																																							
narrative draft																													x										
meeting to finalize SOPs																														x									
finalize protocol																																x							
submit for peer review																																	x						
receive peer comments																																				x			
finalize & wrap-up																																							x

Budget and Staff: Proposed budget summary tables follow for FY06-FY08:

Table 2. ***FY2006 costs.***	**FY2006 I&M funds to CESU**	**FY2006 I&M funds to RCUH**	**FY2006 I&M funds to parks**	**Park in-kind**
Personnel				
PI Jim Beets (1.5 mo)	12,450			
PD Alan Friedlander (1.5 mo)	12,450			
Student research assistant, 4 mo at $9.24 (includes fringe)	6,200			
NPS Lead (GS-11, 3 mo)				4,450
E. Brown (GS-11, 1 mo), KALA				6,500
P. Brown (GS-11, 2 mo), NPSA				7,500
Science Advisor (GS-13, 0.5 mo)				5,700
Facilitator (R. Daniel, 6 mo)		23,600		
Travel				

PI/PD: 4 x Honolulu-Kona/Hilo/KALA	2,200			
Supplies	1,000			
Subtotal		23,600		
Overhead (17.5%)	5,003	4,130		
TOTAL	**66,858**	**27,730**		**30,150**

Table 3. ***FY2007 costs.***	**FY2006 I&M funds to CESU**	**FY2006 I&M funds to RCUH**	**FY2006 I&M funds to parks**	**Park in-kind**
Personnel				
PI Jim Beets (0.5 mo)	4,150			
PD Alan Friedlander (0.5 mo)	4,150			
UH student research assistants (4 mo at $9.24 including fringe benefits)	0*			
Ecologist (GS-11, 4 mo), NPSA				26,700
Ecologist (GS-11, 1 mo), KALA				6,500
Ecologist (GS-9, 2 mo), NPSA				7,500
Science Advisor (GS-13, 0.5 mo)				5,700
Bio Tech (GS-5, 1 mo), NPSA				3,300
Data Manager (GS-11, 3 mo)				?
Facilitator (R. Daniel)		0*		
Travel				
NPS Lead: 1 x NPSA-Hawaii			3,600	
PI/PD: 4 x Kona/Hilo/KALA	2,200			
Materials & Supplies				
Field/office supplies	1,000			
Subtotal	11,500			49,700
Overhead (17.5%)	2,013			
TOTAL	**13,513**		3,600	**$49,700**

*Carryover

Table 4. ***FY2008 costs.***	**FY2006 I&M funds to CESU**	**FY2006 I&M funds to RCUH**	**FY2006 I&M funds to parks**	**Park in-kind**
Personnel				

PI Jim Beets (0.5 mo)	0*			
PD Alan Friedlander (0.5 mo)	0*			
UH student research assistant (1 mo at $9.24 including fringe benefits)	0*			
Ecologist (GS-11, 4 mo), NPSA				26,700
Ecologist (GS-11, 1 mo), KALA				6,700
Ecologist (GS-9, 2 mo), NPSA				7,500
Science Advisor (GS-13, 0.5 mo)				5,700
Bio Tech (GS-5, 1 mo), NPSA				3,300
Data Manager (GS-11, 3 mo)**				?
Facilitator (R. Daniel, 6 mo)		24,600		
Travel				
PI/PD: 4 x HNL-Kona/Hilo	2,200			
NPS Lead: 1 x NPSA-Hawaii			3,600	
Coral Managers' meeting in Hawaii to finalize SOPs			11,500	
Field/office supplies	1,000			
Subtotal	3,200	24,600		49,900
Overhead (17.5%)	560	4,305		
TOTAL	**$3,760**	**28,905**	**15,100**	**$49,900**

*****Carryover

Table 5. ***FY2009 costs.***	**FY2006 I&M funds to CESU**	**FY2006 I&M funds to RCUH**	**FY2006 I&M funds to parks**	**Park in-kind**
Personnel				
PI Jim Beets (0.25 mo)	0*			
PD Alan Friedlander (0.25 mo)	0*			
UH student research assistant (at $9.24 including fringe benefits)				
Ecologist (GS-11, 1 mo), NPSA				6,600
Ecologist (GS-11, 1 mo), KALA				6,700
Ecologist (GS-9, 2 mo), NPSA				6,000
Science Advisor (GS-13, 0.5 mo)				5,700
Data Manager (GS-11, 3 mo)**				?
Facilitator (R. Daniel, 3 mo)		12,300		
Travel				
NPS Lead: 1 x NPSA-Hawaii			3,600	
PI/PD: 4 x HNL-	2,200			

Kona/Hilo/KALA				
Supplies	1,000			
Subtotal	3,200	12,300	3,600	19,600
Overhead (17.5%)	3,343	2,153		
TOTAL	**$22,443**	**14453**	**3,600**	**$19,600**

*****Carryover

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LANDSCAPE DYNAMICS

Prepared by: Sandy Margriter and Page Else (last modified 06/01/06)

Protocol: Landscape Dynamics (Waihona ‘Aina Ho’olilo)

Parks Where Protocol will be Implemented: AMME, NPSA, ALKA, KAHO, PUHO, HAVO, HALE, PUHE, WAPA, USAR

Justification/Issues being addressed:
There are few landscapes remaining on the Earth’s surface that have not been significantly altered or are not being altered by humans in some manner. Land use and land cover change has become a central component in current strategies for managing natural resources and monitoring environmental change. Remote sensing and Geographic Information Systems (GIS) are providing new tools for advanced ecosystem management. The collection of remotely sensed data facilitates the synoptic analyses of earth-system function, patterning, and change at local, regional, and global scales over time; such data also provide a vital link between intensive, localized ecological research and the regional, national, and international conservation and management of biological diversity.

Regional landscape and land use change was ranked 10th among all of the potential vital signs evaluated by the PACN. Alterations in land use and its intensity has the potential of being correlated with all PACN vital sign monitoring, ranging from water quality, soil erosion and deposition, invasive species, and the health of benthic marine communities.

Specific Monitoring Questions and Objectives to be Addressed by the Protocol:

Land Use / Land Cover Mapping

Question 1: What is the current (10 years old or less) land cover / land use within and surrounding PACN parks?

Objective: Map existing land cover at a scale that provides usefull information to managers. For small parks this is likely to be at 1:24,000 scale (or better) using high resolution imagery (4 meters pixel resolution or greater). For larger parks Landsat Imagery may be used to key in on focal changing areas for analysis with higher resolution imagery. Existing HI-GAP and NOAA C-CAP methods and products will be used and adapted to the extent possible.

Justification: Current land cover / land use maps, provided by the USGS, were completed at the 1:100,000 scale. The Hi-Gap landcover was based on Landsat Imagery, again not quite as detailed as park managers need. Although valuable at a regional scale, these maps do not provide a detailed baseline understanding of land use / land cover data for PACN parks.

Question 2: What land use changes (and trends) are occurring within and adjacent to the PACN parks?

Objective 2a: Map land use / land cover for PACN parks every 10 years and use GIS to analyze land use changes.

***Justification**:* In order to evaluate the ecological impacts of land use changes, we must first know what is changing, where changes are taking place and over what time scale.

Objective 2b: Map the distribution and density of infrastructure (e.g. roads and developments) within the wildland-urban interface of PACN parks every 5 years. Use tax assessor and US Census Bureau data, in addition, to map the distribution and density of human habitation (i.e. population and housing density) within the wildland-urban interface surrounding PACN parks every 5-10 years.

Justification: Land use changes and conflicts tend to occur along the wildland-urban interface (or urban sprawl) where homes and other developments are encroaching on public land boundaries such as National Parks. These areas should be monitored more frequently using data sources such as USGS vector data layers, GPS, and remotely sensed imagery. Ancillary data, including county tax assessor records and US Census Bureau surveys, can more accurately quantify the numbers and densities of homes within rural areas.

Basic Approach:

All available information a concerning land use / landscape change conducted within PACN will be considered prior to initiating any new work. Land cover / land use maps (and protocols) have been developed by the NOAA C-CAP / USGS. In addition the Hawaii GAP program has mapped land cover (using a more detailed classification scheme) for the main 8 Hawaiian Islands, using landsat imagery. Co_PI Dr. Barbara Gibson is the director for that project In American Samoa imagery from various sources has been investigated by USFS programs for input to a multi-stage remotely sensed vegetation classification. The goal was to determine what type of imagery or combination of imagery (1:12,000 and 1:24,000 color infrared; IKONOS satellite data; QuickBird satellite data) is most appropriate for identifying vegetation in the tropical Pacific. Landcover classes have been developed and USFS will be collaborating with NPS for development of change dectection methods. Land cover mapping will also be coordinated with other NPS mapping efforts currently taking place at HAVO and planned for HALE. The USGS/NPS vegetation mapping standards will be considered in developing the protocols for mapping land cover. Several networks have developed landuse change protocols and their methodology will be evaluated for application in PACN. The change vector methods of the NCCN protocol will be evaluated by Co-PI, Dr. Barbara Gibson, assisted by Sandy Margriter, NPS, and a graduate student.

Land Use / Land Cover Mapping and Change Detection:
The Landscape Dynamics protocol development will focus on the use of high resolution (1-10 m) mapping utilizing commercially available satellite imagery such as Quickbird or Ikonos and will build on the low resolution (30m – 1 km) mapping efforts using imagery such as Landsat. Differences in landuse and cover over time will be evaluated through comparison of changes between imagery acquisition dates. GIS based methods will also be utilized, looking at indicators of land use change such as increase in road density, population density, housing or industrial infrastructure, and changes in habitat fragmentation.

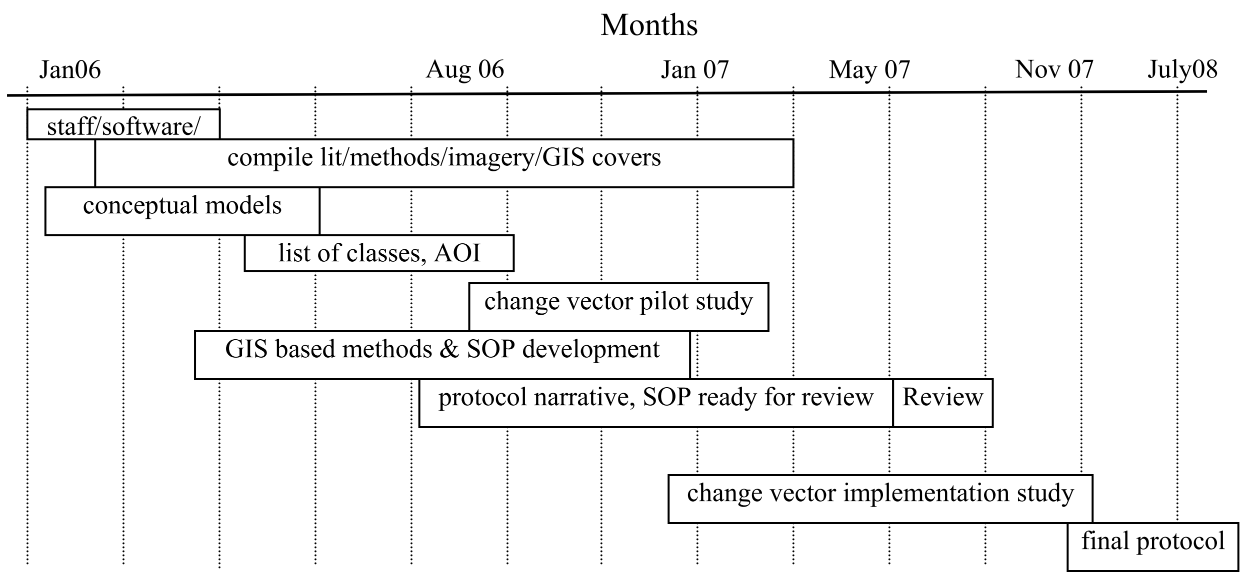
Principal Investigators and NPS Lead:

PIs: Melia Lane-Kamalele, GIS coordinator, PWRO-Honolulu, 808-541-2693 x729, Melia_Lane-Kamahele@nps.gov

Barbara Gibson, University of Hawaii, Director Hawaii Biodiversity Mapping Program, 808-587-8600, bgibson@hawaii.edu
NPS Lead: Sandy Margriter, GIS specialist, PWRO-Honolulu, 808-985-6074, Sandy_Margriter@nps.gov

Development Schedule, Budget, and Expected Interim Products:

Task#	Task Description	Task Duration	Product
1	Obtain equipment / software/staff.	1 week	intrastructure
2	Compile list of data sources, imagery, methods for landscape mapping.	on-going	Metadata database of literature, methods, remote sensing data, GIS layers, hard copy maps.
3	develop conceptual models	1 month	models
4	list of classes and area of interest determined; reviewed by managers	2 months	manager and team agreement on classes, study area
5	change vector analysis pilot study	6 months	determination on feasibility of change vector methodology
6	accuracy assessment of pilot study	1 month	report on pilot study due Feb. 07
7	develop GIS based methods and SOP's for land use portion of protocol	6 months	SOP's plus initial results
8	draft protocol ready for internal review	8 months	draft due April 2007 (progress report due Nov. 2007
9	Peer review of draft monitoring protocol	3 months	begins May 2007
10	implementation studies of change vector methodology with SOP's developed	11 months	progress report due Nov 07
11	final protocol with implementation study adjustments	30 months	protocol due July 2008



Budget Table

	Description	I&M	In-Kind
Salary	GIS Tech. (80% FTE, w/ 33% benefits, 12 months)	$42,400	
	GIS Specialist (GS-11, .25 FTE, in addition to FTE already paid by I&M)		$16,330
	Collaboration with USGS-BRD, TNC, Hawaii-GAP, and NOAA professionals.		priceless
CESU Task Agreement	Change vector methodology analysis	54,050	
Software	Remote sensing / GIS software and extensions	$5,000	
	ERMapper		$8,200
Supplies	Office supplies and misc. field supplies	$7,6830	
Travel:	Interisland trips, conference and class fees (HCC conference) Conservation GIS Advanced Class April 06	$7,180.70 $2,736.30	$ 700
CESU overhead		875.00	
Total		$119,925.00	

The Annual report and work plan specify that this VS received FY2005 $45,875 (or $20,000 less than the initial study plan budget) and so the FY2006 amount was increased a corresponding amount of $20,000 to a net balance equaling $35,600 in FY2006.

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USDA Forest Service http://www.fs.fed.us/r5/spf/about/fhp-pacific-basin.shtml

US NOAA Coastal Change Analysis Program (CCAPS) http://www.csc.notaa.gov/crs/lca/ccap.html

Phase II Vital Signs

Implementation of the following four Phase II Vital Signs (Erosion and deposition, Cave community, Terrestrial invertebrate communities, and Early detection of invasive invertebrates) will be dependent upon successful completion of Phase I Vital Signs, as well as available funding. The protocol development summaries for these Vital Signs are not yet final, and significant changes and updates are anticipated. This particularly applies to the Early detection of invasive invertebrates Vital Sign, which is the least developed. As protocol development summaries for Phase II Vital Signs evolve, they will be similar in structure to those for Phase I Vital Signs and shall contain brief justifications for monitoring, a list of parks in which monitoring will be implemented, specific monitoring questions, detailed monitoring objectives, an outline of proposed methods, timeline and budget, a list of individuals responsible for protocol development, and references.

EROSION AND DEPOSITION

Prepared by: Dwayne Minton (last modified 08/14/05)

Parks where protocol will be implemented:

HALE, KALA, NPSA, PUHE, USAR, WAPA

Justification/issues being addressed:

Erosion and sedimentation are directly indicative of soil disturbance and movement, and therefore, represent a significant threat to terrestrial, aquatic and marine resources. Soils in the PACN tend to occur in limited quantities (e.g. very thin or no soil in many locations) and have variable quality. Loss of soil through erosion can directly result in the wholesale conversion or entire loss of vegetation communities. When suspended in water, fine sediments increase turbidity, decrease light penetration, and alter primary productivity in aquatic systems. Sediments also settle on the bottom and smother benthic organisms such as corals. Any activity that reduces vegetation cover, disturbs the ground, or increases overland water flow will increase erosion and sedimentation rates. These can include anthropogenic land uses such as agriculture, poorly managed development and urbanization, fire and human-induced climate change, which will likely increase the frequency and severity of storms at some of the PACN parks. This vital sign will be monitored at six PACN parks (HALE, KALA, NPSA, PUHE, USAR, WAPA). The remaining PACN parks (ALKA, AMME, HAVO, KAHO, PUHO) do not have significant erosion or deposition issues (excluding volcanic activity). The appropriateness of this vital sign will be re-visited for ALKA once additional information on the park's location is available.

Specific monitoring questions and objectives to be addressed by the protocol:

Question 1: What are the changes over time in soil erosion rates and soil quality measurements (e.g., organic matter, pH, infiltration, aggregate stability, soil crusts) at PACN parks?

Objective 1: Annually assess soil depth, quality (e.g. organic matter, pH, infiltration, aggregate stability, soil crusts), and loss/accretion at randomly selected monitoring sites stratified across rainfall and slope gradients in PACN parks.

Justification: Soils in PACN parks generally occur as a thin layer overlying inhospitable clays or volcanics. Plant communities are intimately linked to soil quality and quantity and processes (e.g. volcanism, erosion, wildland fire, introduced species) that alter these factors can cause significant community-level changes. Additionally, eroded soils can enter streams, ponds and the ocean and increase sediment loads, potentially adversely affecting these ecosystems. Slope and rainfall are important covariates to consider when selecting sampling sites for this objective.

Question 2: What are the changes over time in marine (i.e., coral reefs) and freshwater (i.e., stream) sedimentation?

Objective 2a: Seasonally (wet vs. dry season) measure water column turbidity at randomly selected marine and/or freshwater monitoring sites. Where applicable, monitoring sites should be stratified to monitor point sources (e.g., river mouths, outfall pipes, etc.) and areas away from point sources.

Justification: Suspended sediments can indirectly impact primary producers by reducing light penetration to sessile benthic organisms. This objective will quantify suspended particulate matter in the water column. This parameter is expected to vary seasonally at PACN parks.

Objective 2b: Seasonally (wet vs. dry season) measure the sediment collection rate (load) and determine the percent contribution and total load of the terrestrial soils in marine and/or freshwater sediments at randomly selected, fixed marine and/or freshwater monitoring sites? Where applicable, monitoring sites should be stratified to monitor both point sources (e.g., river mouths, outfall pipes, etc.) and areas away from point sources.

Justification: Sedimentation rate (load) is a direct measure of the suspended matter (excluding re-suspension) settling from the water column onto the benthos. Marine and freshwater sediments are comprised of materials originating from land, freshwater or marine sources. Determining the contribution of terrestrial sources to marine sediments is necessary to assess and manage terrestrial activities. These parameters are expected to vary seasonally at most PACN park.

Basic approach:

A number of existing protocols to monitor erosion and sedimentation are readily available in the literature and through appropriate agencies (e.g. NOAA, NRCS, USGS). A comprehensive review and field testing of these methods is necessary to achieve the program's goal of developing protocols with rigorous scientific merit. Where appropriate, the sampling design will collocate the monitoring for each objective. When to co-locate and with which other vital signs, will be determined after appropriate erosion and deposition methods have been selected. The specific sample design will incorporate guidance provided by the I&M Program (Fancy 2000).

Basic Approach for Objective 1: NRCS has standardized, recommended methods to measure soil quality parameters (NRCS 2003). Several standardized methods to measure soil loss/accretion already have been reviewed in the literature (Hicks 2001), ranging from simple, low technology methods such as erosion pins to complex methods that utilize LIDAR and satellite imagery. Measuring erosion/accretion across a large park is likely not feasible. Therefore, efforts will focus on areas of the park that have been identified as sensitive to erosion or of special interest (e.g., certain locations, features, or terrain types). Within these locations, monitoring should be stratified across slope and rainfall gradients as appropriate. Sampling designs and protocols would not be needed for USAR, because the park has no fast land.

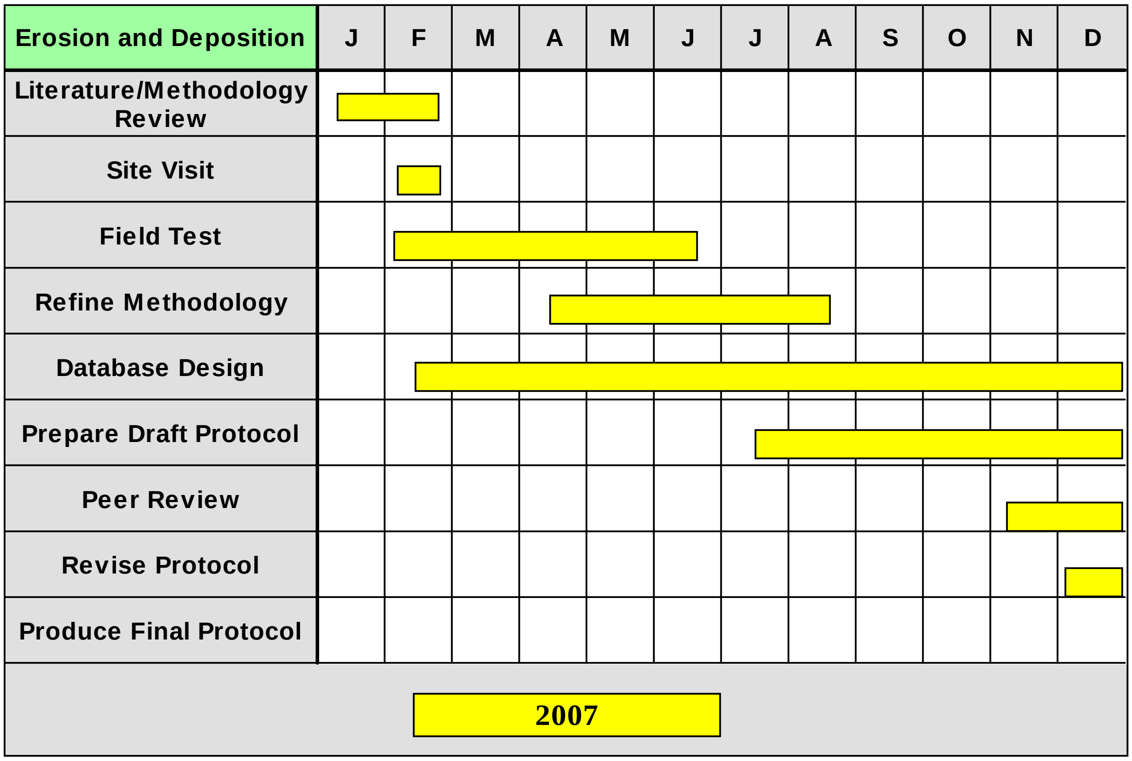
Basic Approach for Objective 2a: Turbidity should be monitored continuously to capture intermittent events such as storms. Turbidity can be measured using readily available automated equipment such as optical back scatter or tranmissometer instrument. Sampling design should be stratified to monitor specific point sources of sediments (e.g. river mouths, outfall pipes, etc.). Park specific designs to monitor areas of special concern (e.g. anchialine ponds, popular SCUBA sites) can also be implemented.

Basic Approach for Objective 2b: Sediment load can be measured using sediment tube-traps or automated sampling equipment. Automated methods are problematic and expensive, but yield data that has finer temporal resolution. Considerable evaluation of the currently available methods and technologies is crucial. The goal of the sampling design should be to measure sedimentation across park waters in a stratified method that will allow the park to examine specific point sources as well as non-point source areas.

Principal investigators and NPS lead:
PI: TBD
NPS Lead: Dwayne Minton, Ecologist-NPS, 671-472-7240, Dwayne_Minton@nps.gov

Development schedule, budget, and expected interim products:
This monitoring protocol will require 12 months to complete and should be started in January 2007 to insure that field testing occurs during the summer months when ocean conditions are optimal for in water work. Rainfall should be adequate in some areas of all parks during this time period to conduct field trials of the terrestrial methods. Based on work conducted at WAPA, six months should be adequate time to obtain results during field testing. A time line is proposed in the listing of tasks below. The development of this protocol is dependent on the schedule of the I&M quantitative ecologist who will be assisting with this protocol.

Table 1.*Timeline of major tasks and products for erosion and deposition protocol development.*



This project will most likely be conducted by contract, interagency agreement with the USGS-GRD. The PACN does not have the on staff expertise to conduct this work. If USGS is selected for this protocol, we will seek funding early in FY07 for the interagency agreement. If this project is funded through a cooperative agreement, we will seek FY06 to insure that the protocol PIs have funding available at the start of FY07.

The final products will include: 1) Final, peer-reviewed monitoring protocol including sampling methodologies, a sampling design, recommended equipment lists, pilot project study report (if appropriate), and bibliography.

References

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CAVE COMMUNITY

Prepared by: Jadelyn Moniz Nakamura (last modified 10/21/05)

Parks where protocol will be implemented:

WAPA, NPSA, HALE, KAHO, PUHO, HAVO

Justification/issues being addressed:

Caves are particularly sensitive to physical disturbance and changes in the outside environment. Key reasons for monitoring cave habitat at PACN parks are: (1) Caves contain pre-Contact Hawaiian ruins and artifacts which provide a wealth of information on early Hawaiian use and adaptation to the landscape, (2) Caves contain geologic information that may hold keys to understanding the formation and history of the islands, and (3) The living ecosystem in park caves harbor examples of endemic, cave-adapted organisms such as blind cave adapted crickets, flightless flies, terrestrial water treaders, and blind big-eyed spiders. Cave habitat ranked 14 among the potential vital signs proposed for monitoring by the PACN network.

Specific monitoring questions that will be addressed by this protocol are:

Question 1: What are the principal threats to cave resources in the PACN parks?

Objective 1a: Compile existing information and develop lists of known caves and cave resources within the PACN parks.

Justification: At least three factors (see below) will be utilized to prioritize caves to be monitored so that a representative sample is obtained.

Objective 1b: Prioritize the list of known caves to identify the caves with significant and vulnerable resources.

Justification: At least three factors (see below) will be utilized to prioritize caves to be monitored so that a representative sample is obtained.

Objective 1c: Select candidate caves with significant resources for long-term monitoring.

Justification: PACN parks have a high number of caves and it is not feasible to monitor each cave.

Question 2: What are the changes over time in the significant natural and cultural cave resources?

Objective 2a: Monitor long term trends in cave arthropod diversity and relative abundance. Specific focus will be on arthropod habitat and community. Determine diversity and change in relative abundance of cave arthropods using timed species counts at prescribed locations within the cave. Photo documentation of the panel sampling sites will determine trends in habitat status.

Justification: Howarth (1982) identified a correlation between evaporation rate and species abundance and distribution. Evaporation rate is influenced by temperature, humidity, and distance from entrances. These data will be used to identify cave arthropod long-term habitat use to better inform management decisions.

Objective 2b: Monitor long term trends in the health of the cave ecosystem. Monitor distribution, abundance, and breakage of tree root patches in caves using photo points and sampling of selected sites within caves and the corresponding surface area above.

Justification: Tree roots are key components in the lifecycle of cave insects, serving as vital food sources. Changing surface vegetation can significantly affect the cave habitat and community structure below.

Objective 2c: Monitor long term trends in the integrity of cultural and geological resources. Specific focus will be on archeological features and unique geologic formations.

Justification: These data will be used to assess the impact of humans on cave habitat and identify the rate of human induced collapse and trampling of ruins structures and unique geologic formations. The data will be used to better inform management decisions and attempt to monitor and document the effects of anthropogenic induced change.

Basic approach:

As core methodological elements in this protocol, we propose to use photo points, cave registers, and remote sensing devices (including aerial photos and satellite imagery) to measure the direct and visual impact of human intrusion on organic artifacts, ruins structures, arthropod habitat and geologic formations. Proposed sampling design includes a time sequence approach to gathering the data. These methods have shown promise in detecting human intrusion. Cave registers are widely used across the United States for recording gross numbers frequency of human use. Photo points and remote sensing devices used in caves at Hawaii Volcanoes National Park have also shown promise as a measure of human activity. We also propose to use temperature and humidity sensors as well as atmometers to measure potential evaporation rate, relative humidity and temperature following the methodology developed by Howarth (1982). Proposed sampling designs to gather data on arthropod diversity and abundance include pit fall traps and temporary bait stations along established transects within the cave. This is a commonly used method for sampling cave insects in the Pacific Islands (Howarth et. al 1994). Sampling of vegetation will include transect and species counts. Data collected using these methods could be used to guide management decisions concerning public entry into caves as well as to monitor the correlation that Howarth (1982) identified between evaporation rate and species abundance and distribution. Six PACN National Parks have been identified for possible implementation of this protocol. All of the parks are either known to contain caves (HAVO, HALE, PUHO, KALA, WAPA), or are believed to contain caves but have not been surveyed (NPSA). The degree to which each park has been previously inventoried for caves varies. Likewise, the degree to which known caves have been inventoried varies. Due to the vast number of caves located in the Pacific Islands National Parks, not all caves can or will be monitored. Only a sample of known caves from each PACN Park targeted for this protocol will be monitored. Selection of caves will be based on 3 factors: (1) presence of cave insects, cultural material and/or geologic formation; (2) proximity to existing trails and/or roads; and (3) location in wilderness. The first factor is critical for the selection of a cave. Priority for selection will be given to caves that contain all three (biological, cultural, geological) variables. If a cave contains all three or at least two of the variables, it will save time in the monitoring process because there will be fewer caves to visit. The second and third factors are critical for monitoring human intrusion. Caves located along roads and trails will likely have more impact by humans than caves in the wilderness. However, it will also be important to monitor the impacts of humans in wilderness caves, as they may represent some previously unknown visitation events and they will serve as good models for comparative purposes. Protocol development for the above objectives will follow a standard procedure, listed below as Tasks. Suggested start time for protocol development is FY2006.

Principal investigators and NPS lead:
Protocol development will be accomplished through collaboration between the Bernice P. Bishop Museum (BPBM) and National Park Service (NPS). Field testing will be accomplished through collaboration with the University of Hawaii at Manoa CESU.

Co-PI: Frank Howarth, Research Entomologist, Cave Explorer, Bishop Museum, 808-848-4164, fhowarth@bishopmuseum.org

NPS Lead and Co-PI: Jadelyn Moniz Nakamura, Archeologist-NPS, 808-985-6136, Jadelyn_Moniz-Nakamura@nps.gov

Development schedule, budget, and expected interim products:
The following table reflects the proposed budget to complete this work.

Table 1. *Schedule of major tasks and products for cave communities protocol development.*

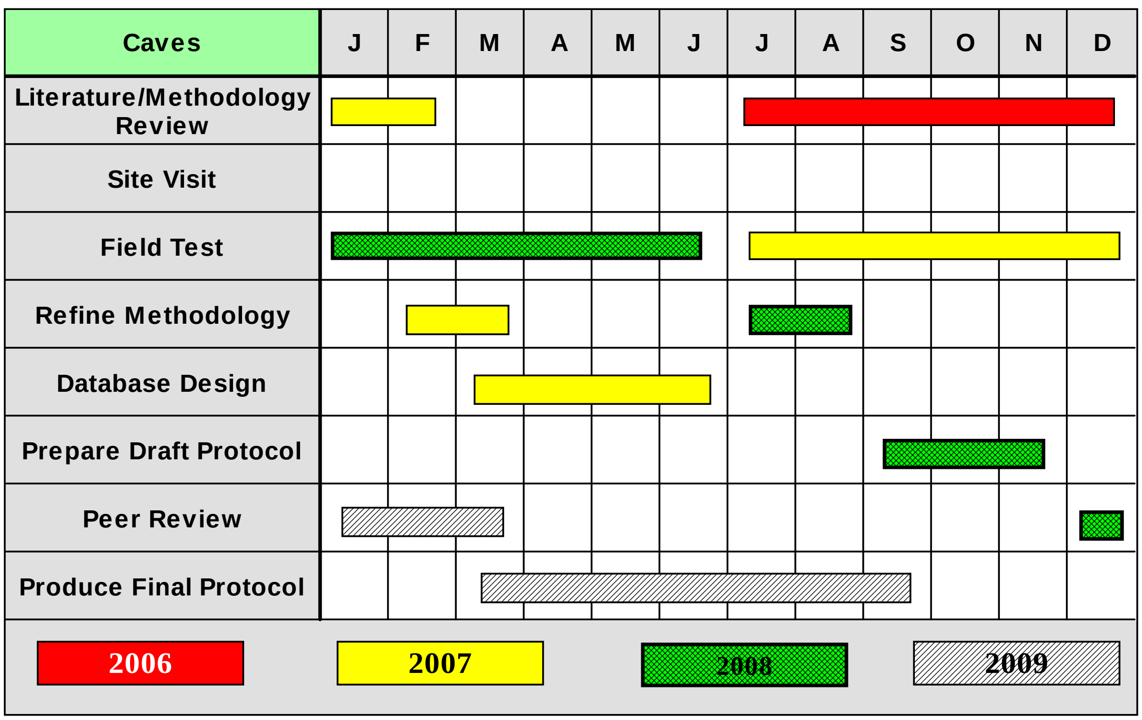

Table 2. *FY2005 and FY2006 budget for cave communities protocol development.*

Budget - FY2005: "Pacific Island Network (PACN) Cave Protocol Development" Principal Investigator: Dr. Frank Howarth, Project Period: 09/30/2005 – 03/30/2009	
Budget Item	**Requested Funds**
A. DIRECT COSTS (FY 05)	
1. Principal Investigator	$42,957.45
2. Printing and Publications	$800.00

3. Travel (Inter-Island for PI)	$2,200.00
SUBTOTAL DIRECT COSTS	*$45,957.45*
B. ADMINISTRATIVE COST (17.5%) (FY 05)	$8,042.55
TOTAL COST OF PROJECT (FY 05)	$54,000.00

Budget – FY2005: "Pacific Island Network (PACN) Protocol Development"	
Principal Investigator: Dr. David Duffy, Project Period: 09/30/2005 – 03/30/2009	
Budget Item	**Requested Funds**
A. DIRECT COSTS (FY 05)	
Salary and benefits for two Archeological Field Technicians for additional PACN cave parks (GS-07 equivalent, 2.0 FTE, @ 1.5 months)	
SUBTOTAL DIRECT COSTS	*$9075.00*
B. ADMINISTRATIVE COST (FY 05)	
5. Administrative Cost (17.5 % on $11,000.00) for additional PACN parks	$1925.00
TOTAL COST OF CESU PROJECT (FY 05)	$11,000.00

Budget - FY2006: "Pacific Island Network (PACN) Cave Protocol Development"	
Principal Investigator: Dr. Frank Howarth, Project Period: 09/30/2005 – 03/30/2009	
Budget Item	**Requested Funds**
A. DIRECT COSTS (FY 06)	
1. Principal Investigator	$40,000.00
2. Printing and Publications	$700.00
3. Travel (Inter-Island for PI)	$1000.00
SUBTOTAL DIRECT COSTS	*$41,700.00*
B. ADMINISTRATIVE COST (17.5%) (FY 06)	$7297.50
TOTAL COST OF PROJECT (FY 06)	$48,997.50

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Terrestrial Invertebrate Communities

Prepared by: David Foote, Karl Magnacca (last modified 08/16/05)

Parks where protocol will be implemented:

AMME, HALE, HAVO, KAHO, KALA, NPSA, PUHE, PUHO, WAPA

Justification/issues being addressed:

The terrestrial invertebrate fauna of the Pacific Islands Network (PACN) is extraordinarily diverse and serves as a model of the evolution of island biotas worldwide. More than 4,000 species of arthropods and other invertebrates have been recorded from Hawaii's National Parks alone, which includes spectacular examples of adaptive radiation. These species also play important functional roles in nutrient cycling, pollination, and as prey for endemic birds and bats. Invertebrates have been generally poorly inventoried and under-monitored in PACN National Parks. However, taxonomically well-characterized endemic taxa (e.g. snails, picture-wing Drosophila, and native bees) are readily monitored, as are highly invasive alien invertebrates (e.g. ants, wasps and slugs). Monitoring of invertebrates will provide critical information and tools for better conservation and management of terrestrial invertebrate communities in the PACN.

The status of terrestrial invertebrate diversity in the PACN is precarious because of the multiplicity of threats from invasive alien plants and animals. At HAVO, HALE, KALA and likely NPSA, wet and mesic forests above 700 meters elevation provide habitat for much of the remaining native biota in these Parks. In Hawaii, while the dominant vegetation of koa, ohia and tree ferns are among the most intact in the state, alien species invasions have seriously degraded components of the native vegetation. The primary stressors are introduced ungulates, such as feral pigs and small mammals. Deliberate introductions of organisms for biological control have also had serious non-target impacts on terrestrial invertebrates. Furthermore, a relatively high proportion of the native insect fauna is either flightless or slow-moving, making it especially vulnerable to predatory social insects, such as ants and yellowjacket wasps (Wilson, 1996). In lowland habitats, ants play a dominant role in limiting native insects to highly xeric habitats particularly, as well as other small refugia (Zimmerman, 1958).

The 1995 Action Agenda in the Strategic Plan for the National Park Service states that "biological diversity is achieved by protecting natural habitats – not just the spectacular species but also the interdependent, less obvious species and systems." The mandate to monitor invertebrate biodiversity in the PACN is strengthened by the designation of IUCN/UN Protected Areas, such as Hawaii Volcanoes (HAVO) and Haleakala (HALE), as International Biosphere Reserves and as World Heritage Sites.

The terrestrial invertebrate fauna of the PACN contains many spectacular examples of island endemism and alien species invasions. It is easy to detect both native and invasive alien elements of this fauna using simple bait traps in order to observe and describe these contrasting terrestrial invertebrate communities. Coupled with species-specific focal searches for especially rare and at-risk taxa, it is possible to use invertebrate communities as monitors of change in Pacific Island ecosystems (e.g. Foote & Carson, 1995a; DiSalvo, et al. 2004). Terrestrial invertebrates are already used worldwide to detect the impact of major environmental stressors, such as climate change and atmospheric pollution. Because of their utility in documenting both the impact of stressors and the success of park habitat restoration activities, terrestrial invertebrate communities were ranked among the top 5 for vital sign implementation by PACN.

Specific monitoring questions and objectives to be addressed by the protocol:

Question 1: What are the seasonal and interannual patterns in species composition and distribution of selected terrestrial invertebrate communities?

Objective 1a: Quarterly determine the relative abundance of terrestrial insects (e.g., flies, bees & butterflies) and other macroinvertebrate (including earthworms, slugs & snails) assemblages at bait stations along belt transects, stratified in representative wet, mesic, and coastal habitats.

Justification: Long-term changes in the relative abundance and distribution of alien and native assemblages of invertebrates can often be correlated with specific stressors or drivers. For example, increases in the relative proportion of alien to native pomace flies can be related to changes in host plant communities, while climate can dictate the rate of spread of invasive Argentine ants (Foote, 1995a, b; Krushelnycky et al., 2004).

Objective 1b: Annually conduct focal searches to detect rare or at-risk invertebrate taxa.

Justification: Endemic snails and pomace flies can be highly localized in distribution (Cowie & Cook, 1999; Kaneshiro & Carson, 1976). The presence or absence of rare species from a specific locality from year to year can be a useful indicator of ecosystem change, and documenting persence or absence is vital for endangered species conservation.

Question 2: How do National Park habitat restoration and alien species control activities affect the species composition and/or abundance of terrestrial invertebrate communities (including earthworms, insects, slugs and snails)?

Objective 2a: Annually measure the relative abundance of native and alien terrestrial invertebrate species in paired treatment and non-treatment resource management sites.

Justification: PACN National Parks are involved in long-term resource management programs for alien species removal and native habitat restoration. These include sites with feral ungulate fencing, invasive plant and invertebrate control, and outplanting of native plant species to restore lost diversity. Long-term monitoring of invertebrate communities (e.g., decades) will provide important feedback to land managers to assess changes in vegetation and disturbance frequency. The measurement of success of habitat management practices should include the protection of native terrestrial invertebrate biodiversity.

Objective 2b: Seasonally (i.e., bimonthly) measure the population size and distribution of invasive predacious social insects, including ants and wasps.

Justification: Alien ants and wasps are major stressors for many native arthropods. Monitoring seasonal trends in distribution and abundance of these alien predators will provide managers with necessary information for the successful implementation of integrated pest management (IPM) programs.

Basic approach:
The high rate of diversity and endemism in the PACN parks that makes terrestrial invertebrates so important also makes it necessary to tailor monitoring protocols to the habitats and taxa relevant to the different parks. To maximize efficiency, the protocols developed will be used for multiple parks and objectives. In addition to appropriateness for monitoring, sites will be chosen based on the ability to monitor multiple groups at the same place. The primary invertebrate communities that need to be monitored in managed sites (Objective 2a) are the same as those targeted for tracking of long-term trends in areas considered to be more stable (Objective 1a). For example, in Hawaii slugs are introduced herbivores that can have serious impacts on native plants. However, when rats (another introduced pest) are controlled, slug populations can explode. Although differing in timing (annual vs. quarterly), objective (tracking impacts of management vs. long-term trends from factors such as climate), and site location, the same protocol can be used for a given taxon in each situation. Protocols are also scalable such that sampling can be performed more intensively if funding allows. The following table gives basic details on methods and sites for the top monitoring priorities. As shown below, the diversity of taxa and habitats means that there is no single sampling scheme that can accomodate all groups and parks.

Taxon	**Parks**	**Habitat**	**Monitoring Method**	**Spatial Method**	**Repeat Time**
Important communities and habitat restoration					
Drosophila pomace flies	HAVO, HALE	wet forest	fermented bait	transects	quarterly/ annual
Hylaeus bees	HAVO, HALE, KALA	dry and mesic forest, coastal strand	pan traps	plots	quarterly/ annual
earthworms	HAVO, HALE	wet forest	soil sampling	plots	quarterly/ annual
slugs	HAVO, HALE	wet forest	beer traps	transects	quarterly/ annual
At-risk species					
Drosophila pomace flies	HAVO, HALE	wet forest	fermented bait	transects	annual
land snails	AMME, NPSA, WAPA	wet and mesic forest	visual search	transects	annual
nymphalid butterflies	WAPA	limestone forest	visual search	transects	annual
Megalagrion koelense damselflies	HAVO, HALE, KALA	wet forest	visual search (naiads)	transects	annual
Invasive social predators					
Vespula wasps	HAVO, HALE, KALA	all forest types	heptyl butyrate traps	transects	bimonthly
Linepithema ants	HAVO, HALE	montane shrubland and forest	meat bait	transects	bimonthly
Anoplolepis and *Pheidole* ants	KAHO, KALA	coast and lowlands	meat bait	transects	bimonthly

There are existing protocols to monitor both alien and native select taxa of terrestrial invertebrates using baits, including bees, pomace flies, ants, wasps, and slugs. Many terrestrial invertebrate species can be readily attracted to baits, using visual (e.g. yellow pan traps for bees; Daly & Magnacca, 2003) and olfactory (e.g. chicken meat for ants and wasps; Gruner & Foote, 2000) stimuli. There are well-developed protocols from practitioners of IPM for the use of baited traps to monitor pest invertebrates. A detailed protocol for sampling bees with pan traps is in development by a consortium of USGS, USDA, and academic researchers (LeBuhn et al., 2003). Other groups are more productively sampled by different methods, such as standardized visual searches for snails (Cowie & Cook, 1999) or soil sampling for earthworms. Protocols for sampling all the taxa above are available from short-term research projects conducted in PACN parks. Before implementing any of these for long-term monitoring as planned, a comparison of the statistical strengths of alternative monitoring techniques for the range of terrestrial habitats represented by PACN parks is required. These methods need to be adapted for use in PACN so as to develop protocols with adequate powers of inference to inform long-term park management activities.

Monitoring protocols will be developed using the following schedule.

Task	Task description	Task Duration	Product
1	Compile and review methods	1 month	Bibliography of relevant methods
2	Assess invertebrate communities at parks	2 months	Using NPSpecies
3	Test alternative baiting strategies at select parks in 3 ecosystem types[1]	2 month	
4	Modify methods to meet specific park conditions	1 month	Draft of Methodology
5	Field test draft methods; collect pilot data[1,2]	6 months	Pilot study report
6	Modify methods to finalize	1 month	Final Methodology
7	Finalize sampling design[2]	1 month	Draft Sampling Design
8	Produce draft monitoring protocol	2 months	Draft Monitoring Protocol
9	Peer review of draft monitoring protocol	3 months	
10	Produce final monitoring protocol	2 months	Final Monitoring Protocol

[1]Task will include an analysis of published baiting and search techniques.
[2]Pilot data will be used to assess statistical validity and power of sampling design.

Principal investigators and NPS lead:

PI: David Foote, Ecologist, USGS-BRD, 808-985-6070, david_foote@usgs.gov
NPS Lead: Tim Tunison, Chief Resources Management-HAVO (Retired)

Development schedule, budget, and expected interim products:

The schedule presented below reflects the estimated duration of tasks required for protocol development. The investigators' ideal start time is early 2006. However, assuming the project starts in January 2006 (FY 2006), it will be ready for peer review in FY 2008. Interim products are listed on the schedule below.

Table 1. *Schedule of major tasks and products for terrestrial invertebrate communities: protocol development.*

Task	Task description	Expected duration	Interim products
1	Review monitoring methods and assess invert. communities.	2 months	Literature review
2	Test alternative baiting strategies at select parks and modify methods to meet specific park conditions	6 months (concurrent with task 1)	Draft stratified sampling design and suggested target species
3	Collect pilot data and evaluate statistical power of alternative monitoring designs.	6 months	Interim report with draft methods.
4	Develop sampling design, finalize analytical, monitoring, and reporting methods.	3 months	Draft protocol: includes sampling design and analytical, monitoring, and reporting methods.

5	Peer review and revision of final monitoring protocols.	4 months	Final protocol.

Budget:	Salary (includes PIs, statistician & technical assistance):	$137,950
	Travel:	$14,400
	Supplies & equipment:	$6,000
	Overhead:	$24,840
	Total:	$183,190

All funds will be dispensed through CESU. This budget does not include in-kind matching funds to be sought from USGS.

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EARLY DETECTION OF INVASIVE INVERTEBRATES

Parks where protocol will be implemented:

AMME, WAPA, NPSA, KALA, HALE, ALKA, PUHE, KAHO, PUHO, HAVO

Justification/issues being addressed:

Invasive alien species pose an enormous threat to the world's biological diversity, believed by most authorities to rank second only to land-use change (Chapin et al., 2000). If biological invasions continue their present course, crude estimates predict the resulting loss of at least 30-35% of the world's species (McKinney, 1998, Zaveleta, 2002). Because of their evolution in relative isolation and in the absence of many forces shaping continental organisms, ecosystems of oceanic islands are particularly vulnerable to invasion by invasive alien species from continents (Loope and Mueller-Dombois, 1989). Not surprisingly Hawaii, a state comprised of isolated oceanic islands, has the most severe non-native species problem of any state in the United States (Office of Technology Assessment, 1993), and other Pacific islands are comparably susceptible. All native habitats and communities in the Pacific island national parks are potentially threatened by new invasions of non-native plants and animals. Due to the special vulnerability of islands, invasive species are likely to overwhelm the national parks of Pacific islands unless NPS is proactive in collaborating with sister agencies and the public to stem the tide of invasions. Involvement in early detection outside park boundaries seems to provide the greatest opportunity for the PACN network to contribute to the collaboration. (Another opportunity involves support for biological control, a necessity for widespread species already causing serious impacts. However, early detection and rapid response are likely to be much more cost effective than biocontrol for those species that are not yet established, since each tested and released biocontrol organism incurs very substantial expense and has been deemed effective in only ca. 20% of cases to date (Julien and Griffiths 1998).)

NPS strategy in the Pacific region is to work with local partners to achieve effective early detection, reporting, assessment, and management. NPS needs to play a major role in collaborative monitoring (surveillance), including the design and implementation outside park boundaries, for the purpose of defending national parks from invasions. In the past decade, partnerships and groups have arisen to address significant gaps in Hawaii's biosecurity system. They include the recently formed Hawaii Invasive Species Council (HISC) to provide state cabinet-level leadership; the Coordinating Group on Alien Pest Species (CGAPS) for interagency and NGO communications and collaborative projects; and the Invasive Species Committees (ISCs) for island-based rapid response.

NPS has been a driving force forging and participating in these partnerships. Each of the Hawaii National Parks is partnered with and supported by the efforts of an island based ISC. ISC's are currently working to protect the parks and other premier natural areas, through rapid response in controlling incipient invasive species threats. Outside of Hawaii, NPSA has recently been instrumental in forming the American Samoa Invasive Species Team (ASIST) which is largely modeled after and envisioned to perform a function similar to the ISC's. Similar interagency groups are in the process of coalescing on Guam and Saipan.

Specific monitoring questions and objectives to be addressed by the protocol:

Questions:

Objectives:

Justification:

Basic approach:

Principal investigators and NPS lead:

Development schedule, budget, and expected interim products:

References: